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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. I.—*An Iodine Titration Voltameter;* by D. Albert Kreider.

The rapidity, accuracy and sharpness of the end reaction of several of the methods of volumetric analysis, particularly of the iodometric methods, have suggested the possibility of applying them to the voltameter. A rather extensive investigation of quantitative electrolytic oxidation and reduction methods, with this aim in view, has resulted in the evolution of a titration voltameter the accuracy of which may be depended upon to about one part in ten thousand. The advantages in point of manipulation and time required, as well as its applicability to a greater range of current density, will, in the writer's opinion, make it of service in many investigations.

The basis of the method is the electrolysis of potassium iodide and the titration of the liberated iodine by sodium thiosulphate. Herroun* first suggested the use of iodine in this connection. He electrolyzed zinc iodide between a platinum anode and zinc cathode in a beaker; but gives the results of only one determination and leaves the method in an impracticable form.

Danneel† reports four comparative tests of Herroun's zinc iodide voltameter in series with a silver voltameter. The results show a difference of between $+0{\cdot}27$ per cent and -1 per cent. His burette readings were made to only the nearest $0{\cdot}1^{cc}$, and the total quantity of thiosulphate was small; varying from $7{\cdot}$ to $34{\cdot}^{cc}$.

The work of Danneel, as well as that of Kistiakowsky‡ on a silver titration voltameter, seems never to have found its way

* Phil. Mag. [5], xl, 91, 1895.
† Zeitschr. für Elect. Chem., iv, 154, 1897.
‡ Zeitschr. Phys. Chem., vi, 97, 1890.

into the general literature. The work of both men, on voltameters, was incidental to another research and the titles of their articles fail to afford any clue to this particular contents. My own preliminary search of possible reactions had been completed and I had settled upon the form of the iodide voltameter before I learned of the work just mentioned.

Herroun rather erroneously points to the high electrochemical equivalent of iodine as its chief advantage; this is obviously immaterial in a volumetric method. As a basis of a titration method, however, iodine has peculiar advantages in the rapid action of sodium thiosulphate upon it and in the extreme sharpness of the end reactions, intensified when desirable by the addition of starch solution. Potassium iodide is, moreover, much to be preferred to the zinc salt. It is obtainable commercially quite free from iodates and its solutions may, therefore, be acidified without the liberation of iodine, except for the very slow action of atmospheric, or dissolved, oxygen.

It is, of course, impracticable to electrolyze the potassium iodide directly, when the liberated iodine is to afford a measure of the current; this is because of the recombination of the electrode products by diffusion. Acidifying prevents this recombination, or even after it has taken place, in an acid solution the original amount of iodine is liberated, providing the iodine has not been allowed to diffuse to the cathode during the electrolysis, where it would tend to combine with hydrogen and would be irrecoverable.

A most satisfactory action is obtained when the anode is submerged in a strong aqueous solution of the potassium iodide under dilute hydrochloric acid in which the cathode is suspended. With the electrodes thus placed vertically, the anode below, the liberated iodine, because of its great density and solubility in potassium iodide, diffuses very slowly. After a run of hours, and even on subsequent standing for hours more, the solution about the cathode remains perfectly colorless and free of iodine.

The Potassium Iodide Cell.

As a cell, I have employed a side-necked test tube, fig. 1, drawn out at the bottom to a long capillary. Into the junction of this capillary a glass rod was ground. The test tube was closed by a rubber stopper with three perforations, through the middle one of which the ground glass rod passes air tight, though not so tightly as to prevent easy motion when moist. The other perforations receive the glass tubes through which the wires connect with the platinum electrodes; anode at the

bottom of the tube, cathode above. The size of the electrodes was, in the small cell, $1{\cdot}6 \times 2{\cdot}7^{cm}$; in the large cell, $2{\cdot}5 \times 6^{cm}$. In the latter case the cathode was somewhat smaller and corrugated. These electrodes were bent into cylindrical form and arranged coaxially with the tube. The smaller cell had a diameter of 2^{cm}, length, 12^{cm}, length of capillary, 7^{cm}. Its capacity was about 30^{cc}; about 7^{cc} being required to cover the anode. The larger cell was made in the same way, of a tube 3^{cm} in diameter and about 15^{cm} in length, with a capillary about 18^{cm} long. With the distance of 5^{cm} between the nearest edges of the electrodes, the total volume required to cover the cathode was about 60^{cc}, about 20^{cc} sufficing to cover the anode.

The apparatus was filled by raising the ground glass rod and by diminished pressure, effected through the side neck, drawing up through the capillary successively the required amount of hydrochloric acid and then the strong solution of potassium iodide in water. In this way the anode is completely submerged in the concentrated solution of iodide without the use of excessive quantities. The hydrochloric acid serves as an electrolyte, permitting the separation of the electrodes sufficiently to preclude the possibility of any interaction of the electrode products.

By this method of filling the cell the iodide is sufficiently acidified, and if not too rapidly drawn in, a sharp line will mark the junction of the two solutions of different density. The electrolysis results in a quantitative liberation of iodine unless the current density is too great. In the latter case oxygen is evolved along with the iodine. With the permissible current densities indicated in Table I, so long as the potassium iodide is not impoverished about the anode, not a trace of oxygen appears and the action is entirely satisfactory. As the iodine is liberated it sinks along the electrode and by its convection effect renews the iodide at the surface of the electrode without the slightest disturbance of the supernatant acid. In all cases where the current density has not exceeded the indicated maximum, or where the duration of the current has not been such as to exhaust the iodide (so that no oxygen is evolved) the supernatant liquid remains perfectly colorless and free of iodine, and continues to show a sharp line of demarcation between the iodine solution and the acid.

Table I shows the possible current densities, potential change, and permissible time of run, under the given conditions. In the first column, the first figure represents the num-

ber of grams of potassium iodide used and the second figure the volume of its solution in water. In the fifth column, where two figures are given, the first represents the fall of potential through the cell at the beginning of the experiment and the second figure that at the end of the run. The interval is found in the sixth column. An asterisk following the figures of the sixth column indicates that the current was continued until, and stopped at the moment of, the first appearance of gas on the anode. It is evident that the liberation of iodine is no longer quantitative for some time before this gas appears, the safety limit depending upon the current density. Within this safety limit the rise of potential is also not as great as that indicated in the fifth column. The fall of potential through the cell increases continuously and very regularly, after the first few minutes, in which it rises rather more rapidly. Just before the appearance of the gas the potential naturally rises quite rapidly. The gradual change of potential is doubtless due to the increased resistance of the potassium chloride solution which is formed during the electrolysis at the boundary of the two solutions. This part of the cell, especially the small one, is always considerably heated by the current, and a conspicuous line of increased density of the solution, but entirely colorless, gradually creeps up the tube to a distance of several centimeters in an hour's run. In the 7th experiment the solution became quite warm and small bubbles of gas appeared on the sides of the glass, long before there was any evidence of gas being evolved at the anode. To test the correctness of the supposition that this was merely dissolved gas, the 8th experiment was made with the cell in a water bath maintained at 9°. Under these conditions no gas appeared until it was evolved at the anode. This experiment also shows that the warming of the solution is, if anything, an advantage; due, doubtless, to the more rapid diffusion of the iodide or to the greater solubility of the iodine. In experiments 3 and 10 the current was varied; the time of run for each value of the current is given in the sixth column.

Three determinations with two of the small cells in series, each containing 2 grams of potassium iodide in 7·5^{cc}, with a current density of 0·015 amp./cm^2 showed the following satisfactory agreement in the amount of thiosulphate required:

(a) { 31·55^{cc} / 31·58" } (b) { 28.60^{cc} / 28.66" } (c) { 16·62^{cc} / 16·60" }

A comparison between the values obtained by two of the iodine voltameters in series with each other and with one or more copper voltameters is shown in Table II. The titrations

in these cases were not as accurately made, nor the solutions standardized with the same care that characterized the later determinations, as will be seen from the sequel.

TABLE I.

(*a*) Small cell { Diam. of cell = 2cm.
Length of cell = 12cm.
Electrodes 1·6 × 2·7cm.
Dist. between nearest edges of electrodes, 5cm.

	KI grms. in cc. of solution	HCl (1:4) cc.	Current (approx.) amp.	Current density (approx.) amp./cm²	P. D. Volts.	Time of run, mins.	
1	1 in 5	not measured	0·13	0·015	2·25	22*	
2	2 " 5	"	0·13	0·015	2·00	35*	
3	2 " 7·5	"	0·25	0·029		15	
		"	0·40	0·046		2 more	
		"	0·5	0·058		4½ more*	
4	2 " 7·5	"	0·5	0·058	7·1 to 7·8	15*	
5	2 " 7·5	20	0·5	0·058	3· " 4·7	13*	Solid iodine at anode
6	4 " 7·5	5	0·5	0·058	5· " 12·5	47*	Solid iodine at anode; Solution alkaline
7	5 " 7·5	20	0·5	0·058	2·4 " 4·8	85*	Solid iodine in large quantity at anode
8	5 " 7·5	20	0·5	0·058	2·6 " 5·8	54*	

(*b*) Large cell { Diam. of cell = 3cm.
Length of cell = 15cm.
Electrode (anode) 2·5 × 6cm.
Distance nearest edges, 5cm.

9	5 " 20	40	0·5	0·017	2· " 3·5	41*	Solid iodine at anode
10	10 " 20	40	0·5	0·017	1·5 " 2·5	91	
			1·0	0·033	4·1 " 4·7	2 more	
			1·5	0·050	5·7	1 more*	Solid iodine at anode

* Gas evolved at anode.

TABLE II.

	Iodine voltameter.							Cu-voltameter.	
	Distance between electrodes, cm.	KI grms. in cc.	Current amp.	Amp./cm²	Time, mins.	$Na_2S_2O_3$ cc.	Copper equivalent, grms.	Copper grms.	Amp./cm²
1	(*a*) 5	4 in 7·5	0·5	0·058	25	73·90	0·2391	0·2379	0·013
	(*b*) 1	4 " 7·5				73·72	0·2385		
2	(*a*) 5	4 " 7·5	0·5	0·058	45	132·87	0·4202	0·4199	0·013
	(*b*) 5	4 " 7·5				132·71	0·4198	0·4203	
3	5	5 " 7·5	0·5	0·058	45	134·21	0·4244	0·4234 0·4240	0·013

Standard Solutions.

Sodium thiosulphate is the most convenient medium for the titration of iodine, but it is not a very satisfactory standard where great accuracy is desired. The salt is readily obtained quite pure, but there is always some uncertainty as to the amount of extraneous water the crystals may contain. Further, on long standing, especially when exposed to the light, it undergoes a slight decomposition, with deposition of sulphur. However, this decomposition is so slow that, if kept in the dark, the solution will remain quite constant for months. In all of my titrations, except those that were merely relative, I have employed an approximately decinormal solution of sodium thiosulphate, standardized against arsenious oxide, by means of an iodine solution. The purest arsenious oxide obtainable was resublimed three times and weighed from a weighing bottle. This solution also was only approximately decinormal. The weight of the arsenious oxide was carefully determined and reduced to its weight in vacuo, and the solution accurately made up to one liter at 20° in a calibrated flask. The direct employment of the arsenic solution for the titrations is undesirable because it necessitates an excess of bicarbonate and the danger of loss of iodine in the neutralization requires a complicated series of traps. Moreover, the end reaction, when starch is employed, is much slower with arsenic than with the thiosulphate. With the latter it is practically instantaneous.

The Titrations.

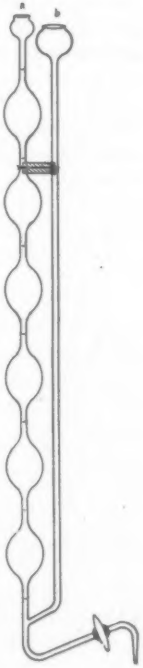
The titrations were performed in Ehrlenmeyer beakers. In filling the cell, care was always taken to draw up the last of the iodide solution as far as the ground glass joint, but without admitting air which would stir up the solutions. To avoid a possible loss of iodine through a considerable leakage of the joint and vaporization from the concentrated solution, the Ehrlenmeyer beaker containing about 150^{cc} of water was placed under the cell during the electrolysis. The capillary extension of the cell (fig. 1) reached to the bottom of the beaker. Whenever the leakage of the ground glass joint was sufficient to allow the iodine solution to descend the full length of the capillary during an experiment, the joint was reground with the finest emery. Under these conditions a loss of iodine is impossible.

After the current was cut off, the ground glass joint was opened slightly and the cell allowed to empty slowly. The great density of the iodine solution keeps it continuously covered with a layer of water of considerable depth in the

beaker, and the supernatant acid of the cell washed out the iodine completely.

A burette of 50^{cc} capacity was employed. This burette was carefully calibrated and was found to be surprisingly accurate. Its error indicates an extremely minute and regular taper of the tube and the graduations are such as to permit of accurate readings to 0·02^{cc}. In fact I have felt considerable confidence in reading it to 0·01^{cc}. This, with the strength of solution employed, was equivalent to about 0·1^{mg} of silver. In the earlier determinations, when more than 50^{cc} of the thiosulphate were required, the burette was in some cases refilled, which, of course, multiplied the error of reading. In other cases, where the amount of thiosulphate was approximately known, a sufficient quantity was added to the beakers from calibrated pipettes of various size, so that the additional amount required should be less than 50^{cc}. This is, of course, less exact and impractical as well, unless the amount required is approximately known.

2



In the later determinations a bulb burette, fig. 2, was employed. This contained 6 bulbs, each of approximately 25^{cc} capacity, connected by small tubes of about 2 to 3^{mm} internal diameter. At about the middle of these tubes marks were etched in such a way as to permit readings without error of parallax. The smallness of the tubes prevented filling the burette from the top and to avoid the uncertainty of rubber connections a small side tube, also about 2 to 3^{mm}, terminating in a funnel, *b*, was sealed on and supported by a section of cork as shown. A finger placed on *a* as the liquid is poured into *b* regulates the flow, so that air bubbles are not carried along and the burette is filled quietly and accurately. Inclining the discharge tube, as shown, is of great advantage in preventing any of the grease from the cock soiling the interior of the burette, a very troublesome feature of the usual burette.

The readings of this burette are naturally extremely accurate. It was employed in bleaching the larger part of the iodine. Experience enabled me to judge from the color about when the remaining iodine was less than that bleached by the contents of one bulb. If there was any difficulty in judging this, a comparison beaker of iodine solution could be employed. At any rate the 50^{cc} burette, with which the titration was com-

pleted, was equal to two of the bulbs, and no difficulty was experienced in keeping within that limit. In case of accidentally overstepping the amount of thiosulphate required, a measured volume of iodine solution may be added and the titration be repeated, subsequent deduction being made for the amount of thiosulphate necessary to bleach the added iodine.

The end reaction was in all cases taken as the bleaching of the iodine color, without starch. This in itself is quite delicate, and I have invariably been able to read it to a small fraction of a drop, when the beaker stood on white paper in a good indirect light. As a confirmation of the reading, 5^{cc} of starch solution was then added and produced a faint purple color. The delicacy of this end reaction was more thoroughly appreciated when, after a number of titrations had been made successively, as in the experiments of Table III, the addition of the starch produced almost precisely the same shade of color in all, despite the fact that a very small fraction of a drop of the thiosulphate produced a distinctly perceptible change in the color.

TABLE III.

	Electrodes, cm.	Dis. bet. electrodes, cm.	KI grms. in cc.	Amperes (approx.)	Amp./cm^2 (approx.)	$Na_2S_2O_3$ cc.	Difference.	
							cc.	%
(1)	1·6×2·7	2	5 in 7·5	0·5	0·058	130·84	0·17	0·13
	1·6×2·7	5	5 " 7·5			130·67		
(2)	1·6×2·7	2	5 " 7·5	0·5	0·058	128·49	0·06	0·047
	1·6×2·7	5	5 " 8·5			128·55		
(3)	1·6×2·7	2	5 " 7·5	0·5	0·058	127·36	0·10	0·078
	2·5×6·0	5	10 " 20		0·017	127·46		
(4)	1·6×2·7	2	5 " 7·5	0·5	0·058	170·67	0·23	0·135
	1·6×2·7	5	5 " 7·5			170·67		
	2·5×6·0	5	10 " 20		0·017	170·90		

Table III is a record of a number of determinations of the constancy of this voltameter. Two or more of the cells were connected in series, and the conditions in each varied as shown. The time of run for 1 to 3 inclusive was about 45 mins., for the 4th, one hour. The amount of hydrochloric acid (1 : 4) was not measured. Enough of the acid was drawn in to insure the covering of the cathode when the iodide solution was drawn in, and to keep the solution acid throughout the experi-

ment. The iodide was roughly weighed. No correction was made for the blank determinations, nor was special care taken to maintain exact constancy of temperature.

Table IV shows the results of the only two determinations that were made by three of the iodine voltameters in series with each other and with one normal silver gravimetric voltameter. The original readings of the burettes for the required thiosulphate is given in the 6th column. In the 7th column is given the value corrected for the blank determinations. A number of blank determinations for the small cell, when 5 grams of iodide were used, gave, with the blank shown in (2), an average value of 0·07^{cc} of thiosulphate, which is the correction applied to all of the small cells. The large cell, with 10 grams of potassium iodide, showed an average value for a blank determination of 0·21^{cc} of thiosulphate. This is three times instead of twice the value of the small cell, as would be expected were the result due to traces of iodate in the iodide. The uncertainty as to the amount of iodine liberated by iodate, or by dissolved oxygen, or by possible oxidizing impurities of the acid, make it rather more desirable to employ known weights of the iodide and known volumes of the acid and then to correct for the blank determination, than the alternative of securing absolute freedom from these extra sources of liberation of iodine.

In the silver voltameter employed, the cathode was a platinum bowl about 8^{cm} in diameter and 3·5^{cm} in depth. The anode was a silver disc, 5·8^{cm} in diameter, 0·8^{mm} thick, and supported by three platinum wires bent over its edges. This was wrapped in filter paper. The solution was made up of 20 grams of pure silver nitrate, dissolved in 106^{cc} of distilled water. The deposited silver was washed with water and allowed to stand under water over-night. Then washed again with water, finally with absolute alcohol and heated for 4 hrs. in an oven at 160°. Then allowed to cool for an hour in a desiccator before weighing.

TABLE IV.

	Electrodes, cm.	Distance between Electrodes, cm.	KI grms. in cc.	Amp. (approx.)	Amp./cm^2 (approx.)	$Na_2S_2O_3$ cc.	$Na_2S_2O_3$ corrected for blank, cc.	Silver equivalent, grms.	Silver (in vac.) ag-voltameter, grms.	Difference. Grms. of silver.	Difference. %
1	1·6×2·7	2	5 in 7·5	0·5	0·058	152·07	152·00	1·63386	1·63236	0·00150	0·092
	1·6×2·7	5	5 " 8·5		0·058	152·06	151·99	1·63375		0·00139	0·085
	2·5×6·0	5	10 " 20		0·017	152·19	151·98	1·63364		0·00128	0·078
2	1·6×2·7	2	5 " 7·5	0·0	0·00	0·06					
	1·6×2·7	5	5 " 7·5	0·5	0·058	156·40	156·33	1·68042	1·67934	0·00106	0·063
	2·5×6·0	5	10 " 20		0·017	156·55	156·34	1·68053		0·00119	0·071

The titrations in the experiments recorded in this table were made with due regard to all possible sources of error. The solutions were brought precisely to the temperature of 20°, at which temperature the room was maintained. The burettes had been thoroughly cleaned with chromate solution, and of course, ample time was allowed for the burettes to drain to a constant reading. The results show that the iodine voltameter, even after the correction for the blank determinations, run uniformly higher by from 0·06 per cent to ·09 per cent; but that they agree among themselves to an order of accuracy of about 1 part in 10,000.

Sloane Physical Laboratory,
Yale University, June 5, 1905.

Art. II.—*The Handling of Precipitates for Solution and Reprecipitation;* by F. A. Gooch.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cxxxv.]

In many processes of analytical chemistry, the preparation of substances in pure condition is brought about by precipitation, solution, and reprecipitation; and sometimes this cycle of operations must be repeated. When a precipitate, gathered upon a filter, is easily acted upon by the appropriate solvent, the process of dissolving the precipitate from the filter is simple; but when the precipitate is refractory toward solvents or difficult to attack on account of its physical condition, as is the case with many gelatinous precipitates, the proper handling of the precipitate involves some inconvenience and delay.

In meeting such difficulties, I have found it advantageous to place within the ordinary paper filter, before filtering, a movable lining of platinum gauze upon which the precipitate rests for the most part and with which it may be removed. The simplest form of this device is easily made by cutting platinum gauze to the shape shown in the accompanying figure. In ordinary use, this piece of gauze, folded to make a cone of angle a little less than 60°, and held by pincers at the point of overlapping, is placed within this filter and allowed to fit itself closely by the natural spring of the gauze when released.

1

Upon filters so prepared a precipitate may be collected and washed as usual; and, at the end of the operation, the cone with nearly all the precipitate may be transferred, by means of ivory-pointed pincers, to dish or beaker for suitable treatment. The small amounts of the precipitate which have passed through the gauze, being somewhat protected by the gauze against the compacting action of filtration and washing, are generally removable with ease from the filter by a jet of the washing-liquid. After washing, the gauze may be replaced within the same filter and serve for a second collection of the precipitate to be subsequently dissolved, in case double precipitation and solution are desirable. The final collection of the precipitate is, of course, made upon paper without the gauze lining, when precipitate and filter are to be ignited.

This device has proved very serviceable in the handling of such precipitates as ferric hydroxide, aluminium bydroxide, and basic acetate precipitations.

I have used also in the manipulation of such precipitates a regularly made cone of 60°, fitted with eyelets for handling; but the simple folded cone is, on the whole, more convenient.

2

Precipitates collected upon asbestos in the perforated crucible are frequently removable without difficulty by allowing a suitable solvent to percolate precipitate and felt; but in case the precipitate is pasty or compacted, solution in this manner may be unpleasantly slow. In such cases, it is convenient to remove the greater part of the precipitate, collected and washed in the usual manner, upon a disc of platinum foil, perforated, fitted with a wire handle, as shown in the figure and placed upon the asbestos felt before the transfer of the precipitate to the crucible. To make such a disc, shown in figure 2, is the work of a few moments only; and by its use pasty precipitates, such as cuprous sulphocyanide or the sulphides of the metals, are easily handled for solution.

These simple devices so facilitate the manipulation of precipitates in many processes of analysis that they have seemed to be worthy of description.

Art. III.—*The Estimation of Sulphites by Iodine;* by R. Harman Ashley.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cxxxvi.]

Volhard's method for the determination of sulphur dioxide and sulphites is accurate and reliable, but involves the inconvenience of making up every solution to be examined accurately to a standard volume of which portions are to be drawn from a burette and made to react with definite amounts of a standardized solution of iodine. The method consists in running the unknown sulphite or sulphurous acid solution into a known amount of a standardized solution of iodine, acidified with hydrochloric acid, to the disappearance of the iodine reaction with starch. This procedure rests upon the facts that the oxidation of sulphite is brought about in the acidified solution and that, as Bunsen showed, no more than a small proportion of hydriodic acid should be present at the point at which the bodies are made to react. The reaction for the oxidation of sulphur dioxide proceeds normally in dilute solutions according to the equation

$$2SO_2 + 2I_2 + 4H_2O = 4HI + 2H_2SO_4.$$

In solutions too concentrated, however, the secondary reaction

$$SO_2 + 4HI = 2I_2 + 2H_2O + S$$

takes place as Volhard has shown*, and vitiates the indications.

To avoid the inconvenience of the Volhard method it has been proposed by Rupp† to bring about the oxidation of sulphites by treatment with an excess of standardized iodine in a solution made alkaline by acid sodium carbonate, and then, after fifteen minutes, to titrate the excess of iodine by sodium thiosulphate. This procedure, however, is, as has been shown by Ruff and Jaroch‡ and by the present writer,§ faulty in principle and practice, and gives correct results only by a chance balancing of opposing errors. Theoretically it might be possible to overcome the difficulties by treating with acid the alkaline mixture of iodine and sulphite and acid sodium carbonate

* Ann. Chem. 242, 93.
† Ber. Dtch. Chem. Ges. xxxv, 3694.
‡ Ber. Dtch. Chem. Ges. xxxviii, 409.
§ This Journal, vol. xiv, p. 237.

before attempting to titrate by sodium thiosulphate the excess of iodine.

In the experiments recorded in the table the following procedure was followed: the sulphite was treated with 1 grm. of acid sodium carbonate and an excess of standardized iodine solution. The solution was then acidulated with a safe amount of hydrochloric acid, it having been found by experiment that the presence of 10^{cm^3} of 1 : 4 hydrochloric acid in 125^{cm^3} of water was without effect upon the determination of iodine by sodium thiosulphate. The excess of iodine after acidification was titrated by standardized sodium thiosulphate. It will be noticed that in the experiments recorded under A of the table, the excess of iodine used was small and in these experiments large negative errors are obtained; while in the experiments recorded under B, in which a large excess of iodine was employed, the results are better. They are best when at least twice as much iodine is added as is theoretically required to oxidize the sulphur dioxide. The length of time during which the iodine may act does not affect the results to any very marked degree.

A

Iodine value of SO_2 taken. grm.	Iodine taken. grm.	Iodine value of $Na_2S_2O_3$ used. grm.	Error. In terms of Iodine. grm.	Error. In terms of SO_2. grm.	Excess of HCl 1 : 4. cm^3.	Vol. at titration. cm^3.
0·2197	0·3143	0·0978	−0·0032	−0·0008	7·5	125
"	"	0·0965	−0·0019	−0·0005	"	"
"	"	0·0970	−0·0024	−0·0006	"	"
0·1535	0·1913	0·0464	−0·0086	−0·0022	"	"
"	"	0·0467	−0·0089	−0·0022	"	"
"	"	0·0472	−0·0094	−0·0024	"	"
"	"	0·0465	−0·0087	−0·0022	"	"
0·2366	0·3194	0·0903	−0·0075	−0·0019	"	"
0·2906	0·3825	0·1132	−0·0213	−0·0054	"	"
0·3825	0·4463	0·0750	−0·0112	−0.0028	"	"

B

0·1143	0·3143	0·1990	+0·0010	+0·0003	5·0	125
"	"	0·1982	+0·0018	+0·0004	"	"
"	"	0·1992	+0·0008	+0·0002	"	"
"	"	0·1986	+0·0014	+0·0003	"	"
0·1482	0·3187	0·1708	−0·0003	−0·0001	7·5	"
0·1576	0·3187	0·1586	+0·0025	+0·0006	"	"
"	"	0·1643	−0·0032	−0·0008	"	"
"	"	0·1598	+0·0013	+0·0003	"	"
"	"	0·1606	+0·0005	+0·0001	"	"
"	"	0·1602	+0·0009	+0·0002	"	"

(B)

Iodine value of SO_2 taken. grm.	Iodine taken. grm.	Iodine value of $Na_2S_2O_3$ used. grm.	Error. In terms of Iodine. grm.	Error. In terms of SO_2. grm.	Excess of HCl 1 : 4 cm^3.	Vol at titration. cm^3.
0·1576	0·3187	0·1622	−0·0011	−0·0003	7·5	125
0·1560	0·3195	0·1660	−0·0025	−0·0006	"	"
0·1992	0·4460	0·2482	−0·0014	−0·0003	"	"
0·1915	0·3825	0·1919	+0·0009	−0·0002	"	"
0·2056	0·3771	0·1701	+0·0014	+0·0003	"	"
"	"	0·1697	+0·0018	+0·0004	"	"
"	"	0·1707	+0·0008	+0·0002	"	"
"	"	0·1709	+0·0006	+0·0002	"	"
[0·2131	0·4470	0·2412	−0·0073	−0·0018]	"	"
0·2354	0·3825	0·1490	−0·0019	−0·0005	"	"
0·2597	0·4463	0·1869	−0·0003	−0·0001	"	"
0·2638	0·4463	0·1847	−0·0022	−0·0005	"	"
0·2908	0·6375	0·3505	−0·0038	−0·0009	"	"
0·3187	0·4463	0·1326	+0·0050	+0·0012	"	"
0·3395	0·6275	0·2842	+0·0038	+0·0009	"	"
"	"	0·2852	+0·0028	+0·0007	"	"
"	"	0·2844	+0·0036	+0·0009	"	"
"	"	0·2855	+0·0025	+0·0006	"	"

Ruff and Jaroch* take the ground that in the favorable results occasionally obtained by Rupp's process, an error due to the over-oxidation of the tetrathionate normally formed in the action of sodium thiosulphate upon the residual iodine is apparently balanced by some oxidation of sulphur dioxide by dissolved air, the iodine in solution acting catalytically as well as directly. The theory, however, is quite at variance with the evidence supplied in the table: for, if it were true, under no conditions could iodine in the presence of air act as a correct measure of sulphur dioxide, as it apparently does when used in a sufficiently large excess; nor does the theory of the catalytic action of iodine explain the fact that when a greater mass of iodine is used, under conditions otherwise similar, we get a larger oxidation of sulphur dioxide.

The most obvious explanation is that at a low concentration of iodine an intermediate oxidation product may be formed and that the formation of this product may be prevented by sufficient concentration of the iodine. It is not unreasonable to suppose that the formation of a small amount of dithionate instead of sulphate is the occasion of the deficient expenditure of iodine noted when the concentration of this element is low, and that the dithionate is not formed appreciably when the

* Loc. cit.

iodine concentration is high. The dithionate once formed is but slowly attacked by iodine, and that is apparently the reason why long standing of the mixtures containing a small proportion of iodine does not result in complete oxidation of the sulphite to sulphate. From these considerations it will be seen that the secondary error of Rupp's process may very probably be due to the formation of some dithionate from the sulphite where the concentration of the iodine is low.

The practical estimation of sulphurous acid or a soluble sulphite may, then, be accomplished with a reasonable degree of accuracy by adding to the solution of the substance, not exceeding 100^{cm^3} in volume and containing a gram of acid sodium carbonate, at least twice as much iodine as is theoretically necessary to effect oxidation, acidifying cautiously with hydrochloric acid, and determining with standard sodium thiosulphate the excess of iodine remaining in the acidified solution.

The author takes this occasion to thank Prof. F. A. Gooch for much kind assistance.

ART. IV. — *Revision of the New York Helderbergian Crinoids;** by MIGNON TALBOT. (With Plates I–IV.)

THIS paper treats of the Crinoidea of the Helderbergian rocks of New York, and is a continuation of Dr. George H. Girty's thesis, "A Revision of the Sponges and Coelenterates of the Lower Helderberg Group of New York." In Dr. Girty's paper, the term "Lower Helderberg" included the Tentaculite, or Manlius, limestone; but here "Helderbergian," as proposed by Clarke and Schuchert,† is used to include only the Coeymans, or Lower Pentamerus; the New Scotland, or Delthyris Shaly; and the Becraft, or Upper Pentamerus.

With the exception of the work done by Wachsmuth and Springer, who probably used specimens that Hall had studied, the crinoids of the Helderbergian rocks of New York have not received much attention since Hall's descriptions were published, in 1859. Very little subsequent collecting has been done, and for the most part the forms secured have been specimens of *Homocrinus scoparius* and *Edriocrinus pocilliformis* or simply stem fragments, the work of gathering being done in the New Scotland.

A reopening of the old locality at Jerusalem Hill was made, however, in 1901, by Professors Beecher and Schuchert; and a new locality was discovered at North Litchfield, both of these being in the Coeymans limestone. The majority of fossils found were crinoids, but there were also cystids in appreciable numbers and five ophiuroids representing two genera. In the fall of 1903, these collections were increased by more material collected at the same locality by Mr. C. J. Sarle; so that in the Yale University Museum there are now three collections—one from Jerusalem Hill and two from North Litchfield.

The first of these consists mainly of *Homocrinus scoparius*, though it contains uncompressed forms of *Cordylocrinus plumosus* and several good specimens of *Melocrinus pachydactylus*. In the region of Litchfield, the Coeymans limestone attains a thickness of one hundred and fifty feet and *Homo-*

* This paper is part of a thesis presented to the Graduate Faculty of Yale University for the degree of Doctor of Philosophy, in June, 1904. The larger part of the work was done under the supervision of the late Professor Charles Emerson Beecher, for whose help and inspiration the writer wishes to make the most grateful acknowledgment. Type specimens have been studied in the Yale University Museum, the New York State Museum and the American Museum of Natural History; and the thanks of the writer are here expressed to Professor R. P. Whitfield, Dr. J. M. Clarke, Dr. E. O. Hovey and Mr. H. H. Hindshaw, for courtesies in connection with the study, and to Professor Charles Schuchert, who took up the direction of the work after Professor Beecher's death.

† Science, New Series, vol. x, p. 876, 1899.

crinus scoparius is said to range from the Manlius almost to the top of the Coeymans. Most of the specimens in the Yale collection were found about forty-six feet from the top of the section in a twelve-inch layer containing slabs rich in *Homocrinus scoparius* and also specimens of *Melocrinus pachydactylus*, *Anomalocystites cornutus*, *Lepocrinites gebhardi* and the ophiuroids. *Cordylocrinus plumosus* is abundant in the lower bed mentioned later.

The collection from North Litchfield is chiefly from two horizons and is extremely rich. One of these beds is a limestone four inches thick in which are specimens of *Melocrinus nobilissimus* with very large crowns and very stout, long stems and a large form of *Cordylocrinus plumosus* in comparative abundance, the majority of the individuals showing many long cirri crowding around the calyx. The material from this zone has one specimen of *Lepocrinites gebhardi* and several of *Homocrinus scoparius*. Although all the fossils in this bed are of large size, especially is this true of *Melocrinus nobilissimus*, whose columns are very thick and, though only fragments, measure from fifty to seventy centimeters in length. This is long for Paleozoic crinoids. Wachsmuth and Springer state that no columns over three feet in length have been seen from the Paleozoic and that generally they are not over one foot long.* Here there are numbers over two feet in length.

The other horizon, a few inches higher in the section, has furnished slabs covering a floor space of some sixty-five square feet, slabs that are literally covered with crinoid stems and crowns. Here, too, as in the lower bed, are stems over two feet long. The forms represented are *Mariacrinus beecheri*, *Melocrinus nobilissimus*, *M. pachydactylus*, *Thysanocrinus arborescens* and *Cordylocrinus plumosus*. To show the relative abundance of these species, an enumeration of the individuals on the slabs was taken and by actual count there were found, of *Mariacrinus beecheri* thirty-one specimens, of *Melocrinus nobilissimus* six, of *M. pachydactylus* one, of *Thysanocrinus arborescens* ten, and of *Cordylocrinus plumosus* eight hundred and seventy-three, making a total of nine hundred and twenty-one specimens. In addition to these are numerous crinoid columns, several gastropods and brachiopods and one cephalopod. On a small surface of six square feet there are three hundred and twenty crinoids.

The cover of this bed is also in the collection and it is estimated that two-thirds as many more crinoids are on its lower surface. This enumeration was made before anything was done toward developing the slabs and such preparation may

*North American Crinoidea Camerata, vol. i, p. 39; Mem. Mus. Comp. Zool., Harvard College, vol. xx, Cambridge, Mass., May, 1897.

double the number now visible; hence in this one collection, there are undoubtedly more crinoids than in all other collections from New York combined.

The following species, listed by Hall from the Coeymans limestone at North Litchfield, have not been recognized in the Yale material: *Mariacrinus paucidactylus* (probably *Melocrinus pachydactylus*), *M. ramosus*, *M. plumosus*, *Platycrinus parvus* (probably *Cordylocrinus plumosus*), *P. ramulosus* (seems to be restricted to the Cobleskill zone of the Manlius) and *P. tentaculatus*. This is not to be wondered at, however, as a slight change of position, horizontally or vertically, often reveals a different fauna; and as Hall's collections represented gatherings not only from the quarries but also from the stone walls about the town of Litchfield, the fossils undoubtedly came from different horizons and localities.

In the classification, nomenclature and terminology of the crinoids, Wachsmuth and Springer have been followed and the reader is referred to their works, "The North American Crinoidea Camerata"* and "The Revision of the Palæocrinoidea."†

Order, INADUNATA Wachsmuth and Springer.

Suborder, FISTULATA, Wachsmuth and Springer.

Family, *Cyathocrinidæ* Roemer.

Genus, *Homocrinus* Hall.

Homocrinus scoparius Hall. Plate III, figure 3.

Homocrinus scoparius Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 102, pl. 1, figs. 1–9.—Wachsmuth and Springer, Rev. Palæocr., Pt. I, 1879, p. 79; Proc. Phila. Acad. Nat. Sci., vol. xxxi, 1880, p. 302.—Bather, Kongl. Svenska Vet. Akad., Handl. xxv, 1893, p. 105.

In the collection of crinoids from Jerusalem Hill, N. Y., now in the Yale University Museum, there is a considerable number of slabs showing *Homocrinus scoparius* in abundance. These slabs vary in size from a few centimeters to over half a meter in length and the surfaces are virtually covered with these beautiful fossils. One slab, thirty centimeters long and twenty-three wide, has eighteen specimens, three of which are complete, that is, have the crown and the whole length of the column, including the distal end. Aside from these, there are four other stems and two (possibly three) specimens of *Anomalocystites cornutus* on the same slab. On other slabs from the same horizon are *Melocrinus pachydactylus*, *Anomalocystites cornutus*, *Protaster forbesi*, and *Dalmanites sp. (?)*. Many

* Memoirs of the Museum of Comparative Zoology at Harvard College, vols. xx and xxi, with Atlas, Cambridge, Massachusetts, May, 1897.

† Proceedings of the Philadelphia Academy of Natural Sciences, vols. xxxi, xxxiii, xxxvii and xxxviii.

of the specimens of *Homocrinus* are in almost perfect condition, and where the fine cirri are visible on the stem the grace and delicacy of this species are well shown (pl. III, fig. 3).

The following additions are made to Hall's description :—

Ventral sac strong, elongated, sometimes three-fourths as long as the arms, the upper part composed of vertical rows of small hexagonal plates. The upper end of the sac probably has five large plates, which are drawn out into spines, something like those in *Scaphiocrinus unicus*. Three of these spines and traces of a fourth can be seen in one specimen, and their position shows that a fifth was probably present originally. These spines are not scattered irregularly over the upper surface, as is indicated in Hall's figure. Column long and slender, consisting of irregularly alternating larger and smaller joints, round below and becoming obtusely angular and enlarged above. Canal small and round. Shortest column observed 4^{cm} in length ; longest, which is still incomplete, 15^{cm} long. Very delicate cirri are preserved, but in no specimen are they found above the middle of the stem. Wherever the distal end of the column is present, there is a coil or loop, as if the stem twined around some support (pl. III, fig. 3). No indications of the clustering of columns mentioned by Hall were seen in the Yale collection.

Horizon and locality.—Common in the thinly laminated or shaly layers of the Coeymans or Lower Pentamerus, at Schoharie, Jerusalem Hill and North Litchfield. Hall reports the species from the Manlius, or Tentaculite, limestone,* but no such specimens have come under the writer's observation.

Cotypes (used by Wachsmuth and Springer for the revised genus) in the American Museum of Natural History, from Litchfield, N. Y.

Family, *Edriocrinidæ* n. fam.

In the specimens of *Edriocrinus* under observation, there are differences that at first seemed to have specific, if not generic value. There are two quite common forms—one (No. 1 and No. 2)† the small hemispherical cups, so well known to collectors in the Helderberg Mountains; and another (No. 3) like the preceding only that the cup has a prominent band or ring around the upper margin. There are other forms that are not so common, however; and they can be divided into two groups, or even three. One specimen (No. 4) about twice as high as the common ones has the hemispherical cup, above which and fused to which is a solid band; and above this still another band of six fused plates, twice as high as the lower

* Nat. Hist. N. Y., Pal., vol. iii, p. 103, 1859.
† Numbers refer to those on pl. IV, figs. 1–6.

band. Another individual (No. 5) does not show the first band, and the second is broken up by weathering into five comparatively broad plates and one narrow one. The next specimen to attract attention (No. 6) resembles the one just described only that on one side the plates succeeding the cup have the appearance of a row of three short plates, instead of one high one.

It was not until these forms, seemingly so different, had been most carefully compared that any conclusion concerning them could be reached. The difficulty was due, mainly, to the fact that in most cases the suture lines are wholly obliterated; but, with a trace of a suture here and another there, there was something on which to base an interpretation. The following solution is offered:

The genus *Agassizocrinus* is said to be dicyclic because young specimens have infrabasals, although the latter are obliterated before maturity is attained. The question has arisen, Why may not the same be true of *Edriocrinus?* By following out this idea, these seemingly distinct forms were reduced to two whose difference is simply in the development of the basals, which in one group are inconspicuous and in the other are enlarged to form the prominent ring or band mentioned above.

The explanation of these varying specimens is as follows: No. 2 and No. 5, instead of being monocylic, are dicyclic, the infrabasals, which are the largest, being fused with the basals. No. 3 shows infrabasals and basals, the latter being very prominently developed. No. 6 has infrabasals and fractured radials, but no brachials. This conclusion has been reached by comparing opposite sides of the same specimen. Though on one side there seems to be a short radial followed by two short brachials in each ray, the other side shows no such division; and it is evident that the apparent brachials are due to the transverse breaking of the radials. This view is supported by the fact that the anal plate is as high as the radials and the apparent brachials combined. No. 4 shows all the plates of the calyx and furnishes the clue to the others. The prominence of the basals is hardly a specific characteristic and these specimens are all left in the original species, *E. pocilliformis.* In the Yale collection, there is one example of *E. sacculus* which gives faint indications of the presence of infrabasals, though none of the specimens show any thickening of the basal ring.

In regard to classification, these forms certainly cannot belong with the genus *Agassizocrinus* in the family Astylocrinidæ, where *Edriocrinus* was placed provisionally by Wachs-

muth and Springer,* because there are no supplementary anal plates in the calyx, as is the case in *Agassizocrinus*. Bather lists the genus provisionally under the order *Flexibilia*,† an order with no anal plate in the cup; but, as *Edriocrinus* has such a plate, the genus cannot be so referred. The calyx structure is that of the Cyathocrinidæ but there are differences that prevent the reference of *Edriocrinus* to this family. The absence of a column is one of these differences and the manner in which the rays divide is another. In *Cyathocrinus*, which is the most representative genus of the family, the arms in branching spread out irregularly, and the joints are generally higher than wide; while in *Edriocrinus* the joints are very short, and the arms branch as do those of *Ichthyocrinus*, the divisions remaining in contact and curling inward. The arms, however, do not form a part of the calyx as in the last named genus.

Family description.—Calyx elongate. Base dicyclic, probably five fused plates in each order. Radials with facets for the insertion of the brachials extending across the whole width. Arms incurved, seemingly without pinnules, divisions remaining in contact; joints much wider than long. Column wanting, the attachment being by the infrabasals in the young stages; mature forms unattached.

Genus, *Edriocrinus* Hall.

Edriocrinus Hall.

Edriocrinus Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 119; 15th Rept. N. Y. St. Cab. Nat. Hist., 1862, p. 115.—Meek and Worthen, Geol. Rept. Ill., vol. iii, 1868, p. 119.—Wachsmuth and Springer, Rev. Palæocr., Pt. I, 1879, p. 21, Pt. III, 1885, p. 10, and 1886, pp. 192, 265, 286; Proc. Phila. Acad. Nat. Sci., vol. xxxi, 1880, p. 244, vol. xxxvii, 1886, p. 232, and vol. xxxviii, 1887, pp. 116, 189, 210; N. Am. Cri. Cam., vol. i, 1897, pp. 59 and 145.—Zittel, Handb. d. Palæontol., I Band, 1880, p. 350.—P. H. Carpenter, Ann. Mag. Nat. Hist., May, 1883, p. 333.—Bather, Rept. Brit. Assoc. Adv. Sci. for 1898, p. 923; A Treatise on Zoology, 1900, Pt. III. The Echinoderma, p. 191.

Amended generic description.—Caylx directly cemented, either throughout life or only in the young stages, the attachment being by the large infrabasals. The cicatrix very large in some specimens and in others obliterated, by the accumulation of calcareous matter on the outer surface of the calyx plates. Infrabasals large, their height being from one-half to two-thirds that of the cup as ordinarily found, completely fused so as to destroy suture lines and to make the number of plates uncertain. Basals five, height varying in proportion to that of

* Rev. Palæocr., Pt. III, p. 192, 1885, or Proc. Phila. Acad. Nat. Sci., vol. xxxviii, p. 116.

† Rept. Brit. Assoc. Adv. Sci. for 1898, p. 923; also The Echinoderma, p. 191, 1900.

the infrabasals, generally so fused as to show no suture lines on the outer surface, although they are often seen on the inner side. Upper margin scalloped for the attachment of the radials and the anal plate. Radials five, large, rectangular, the upper margin excavated slightly for the attachment of the brachials and the lower curved to fit into the concave upper margin of the basals. An anal plate half as wide as the radials and a small plate above it furnish all that is known of the anal area. Ventral surface unknown. Arms known in only one species, *E. sacculus*, where they consist of very short transverse plates and bifurcate several times, but show no trace of pinnules.

Genotype, *E. pocilliformis* Hall.

Edriocrinus pocilliformis Hall. Plate IV, figures 1–6.

Edriocrinus pocilliformis Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 121, pl. v, figs. 8–12.—Meek and Worthen, Geol. Rept. Ill., vol. iii, 1868. p. 370, pl. 7, figs. 5a and 5b.—Wachsmuth and Springer, Rev. Palæocr., Pt. III, 1886, p. 266; Proc. Phila. Acad. Nat. Sci., vol. xxxviii, 1887, p. 190.—Keyes, Geol. Surv. Mo., vol. iv, 1894, p. 221, pl. xxx, fig. 7.

Amended specific description.—Infrabasals present but so fused that their number is uncertain. Height from one-half to two-thirds that of the cup as ordinarily found. Basals five, completely fused with each other and with the infrabasals or distinguished from the latter as a narrow protruding band. Suture lines sometimes apparent on the interior. Upper margin scalloped for the attachment of the radials and the anal plate. Height about half that of the infrabasals. Radials five, often as high as the infrabasals and basals combined, and, like them, fused to form a part of the cup. In most instances, however, the suture lines between the radials are plainly discernible. As a rule, the union between the radials and basals is not so strong as that of basals with infrabasals; and the cup is generally broken off at the top of the basals. Since in no specimens are brachials preserved, the union of brachials with radials must have been still weaker. Anal plate as high as the radials, but only half as wide. Radials and anal gently convex, sloping in all directions from the center of the plate. Arms and ventral disk unknown. The attachment scar is visible on a number of specimens, and in some is a short distance up on the side of the cup, rather than on the bottom.

Horizon and locality.—Throughout the New Scotland limestone in Helderberg Mountains.

Cotypes in the American Museum of Natural History.

Order, CAMERATA Wachsmuth and Springer.

Family, *Thysanocrinidæ* Wachsmuth and Springer.

Genus, *Thysanocrinus* Hall.

Thysanocrinus arborescens n. sp. Plate I, figure 2; text-figure 1.

Although, in America, no members of this genus have been reported above the Niagara, a number of crinoids that must

be referred to this genus is found in one of the beds of the Coeymans limestone at North Litchfield. The generic features, as given by Wachsmuth and Springer,* are well marked—the subglobose calyx, urn or bell-shaped; infrabasals five, small, barely protruding beyond the column; basals five, the posterior one truncated by a large anal plate; radials five, considerably larger than the costals; costals two; arms ten or twenty, rather strong and biserial; pinnules long; first interbrachial large, followed by smaller ones; anal side wider, first anal plate followed by three in the next row.

The specimens under examination lack the ridges which are so conspicuous in marking the rays in most of the species of *Thysanocrinus;* their plates are smooth, instead of being sculptured as is generally the case in this genus, and the column is pentangular, while in most of the species it is round. The specimens resemble *T. liliiformis* more closely than any other species, but differ from it in the pentangular column and the absence of the ridges on the radial series of plates. Not enough is known about the bifurcation of the arms in *T. liliiformis* to make comparison.

Text-figure 1.—Diagram of *Thysanocrinus arborescens* showing position of the anal plates and first bifurcation of the arms.

Specific description.—Calyx subglobose. Surface of plates smooth. Infrabasals five, small, projecting slightly beyond the column. Basals five, large, hexagonal, the posterior one heptagonal and truncated above to receive the anal plate. Radials five, somewhat larger than the basals, pentagonal. Costals two, half as large as the radials, hexagonal, the second smaller than the first and supporting on its sloping upper margins the two rows of distichals, the lower three of which are larger than the succeeding ones and are embodied in the calyx. Interbrachials, two ranges of large plates followed by smaller ones. Anal plate large, followed by three much smaller ones in the next row. Arms biserial. Each ray bifurcates on the second costal and again on the fourteenth distichal. A third bifurcation occurs, seemingly only on the inner branches and at different intervals in the different arms, varying from the fourteenth to the twenty-third palmar. Pinnules found on the fifth distichal and continuing to the tips of the arms. Column pentagonal. Near the calyx, the joints alternate in size; but farther down the stem every fourth joint is larger. In a specimen in which the crown is 29^{mm} in length, the column, though incomplete, is 40^{cm} long.

* N. Am. Cri. Cam., vol. i, p. 190, 1897.

This species is associated with *Melocrinus nobilissimus*, *M. pachydactylus*, *Mariacrinus beecheri*, and *Cordylocrinus plumosus*.

Horizon and locality.—Upper third of the Coeymans limestone at North Litchfield.

Holotype in the Yale University Museum.

Family, *Melocrinidæ* Roemer.

Subfamily, *Melocrininæ*.

Genus, *Mariacrinus* Hall.

In re-diagnosing the genera *Mariacrinus* and *Melocrinus*, Wachsmuth and Springer recognized the fact that the arms of the former remain apart and do not form the tubular appendage which is so conspicuous in *Melocrinus*. The only species in the Yale collection that shows this characteristic of *Mariacrinus* is a new species, *M. beecheri*, in which the proximal end of the ray forms a tube while the distal end is divided, the arms diverging conspicuously. The species is thus seen to hold a position intermediate between *Mariacrinus* and *Melocrinus*. As the features of the former are more strongly developed, this species is referred to that genus.

Genotype, *M. plumosus* Hall.

Mariacrinus beecheri n. sp. Plate I, figure 3; text-figure 2.

This species bears a resemblance to *Melocrinus nobilissimus* but differs from it in features other than the division of the rays. The auxiliary arm, instead of being comparatively inconspicuous, as in *Melocrinus*, is strong and prominent and lies alongside the tube.

The joints of the rays are longer than those of *M. nobilissimus*, so that, although the arms are given off more frequently than in the last named species, they seem to take origin at greater intervals. As in *M. nobilissimus*, the stem joints alternate in size, but they are so very thin in all parts of the stem, and especially so near the crown, that there is no difficulty in determining this form by the column alone. The column is also much larger in proportion to the size of the calyx.

Text-figure 2.—Anal sac of *Melocrinus beecheri* with *a*, *b* and *c* as the last of the anal series of plates in the cup. × 4½.

Specific description.—Calyx small, elongate, once and a half as long as wide, the increase in width being very gradual. Basals wider than long, pentagonal, not forming a projecting cup, but continuing the width of the column. Radials five, four heptagonal and one hexagonal. Costals two, the first hexagonal, more than half as large as the radials, and the second smaller, pentagonal, and support-

ing two rows of distichals, three in each row. The last distichal supports two rows of palmars, whose first two plates are connected. Above this point, the palmars separate, those on the outside of the ray forming an auxiliary arm which lies alongside the ray but is not connected with it. The inner row of palmars joins corresponding plates from the other row of distichals to form a tubular appendage which extends for a short distance only, when the divisions separate and remain apart to the end of the ray. On the outer side of the ray, arms arise from every fourth or fifth joint; but, on account of the length of the joints, the arms are quite far apart. The arms are biserial to the end. The first interbrachial is large, hexagonal, followed by a double row of alternating hexagonal plates. Anal interradius wider and ending in a short thick tube or sac, composed of numerous plates which seem to have been hexagonal originally. This sac is seen in but one specimen, where the plates are very poorly preserved (text-fig. 2). Column circular, with diameter large in proportion to the size of the calyx. Distally the joints alternate in size, but near the calyx they are very thin and of uniform thickness.

Horizon and locality.—Upper third of the Coeymans limestone at North Litchfield.

Cotypes in the Yale University Museum.

Genus, *Melocrinus* Goldfuss.

Genotype, *Mariacrinus nobilissimus* Hall.

Melocrinus nobilissimus (Hall). **Plate II.**

Mariacrinus nobilissimus Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 105, pl. 2, figs. 1–5; pl. 2A, fig. 1.

Melocrinus nobilissimus Wachsmuth and Springer, Rev. Palaeocr., Pt. II, 1881, p. 122; Proc. Phila. Acad. Nat. Sci., vol. xxxiii, 1882, p. 296; N. Am. Cri. Cam., vol. i, 1897, p. 295; Atlas, pl. xxiii, figs. 1a, 2 and 3.—Bather, A Treatise on Zoology, 1900, Pt. III. The Echinoderma, p. 161, text-fig. lxxiv, 2.

Sixteen individuals of this species have been added recently to the Yale collections; yet, since the type specimen is so nearly perfect, very little additional knowledge has been gained from this new material. Attention, however, may be called to a few points. One specimen shows a row of three or four small plates between the auxiliary arm and the tubular appendage. These plates appear in the figures given by Wachsmuth and Springer, but no mention is made of them in the descriptions. They seem to be interpalmars, though it is possible that they belong to the ventral disk. The domelike extension of the anal series of plates, which is also figured by Hall, is seen indistinctly in one specimen. One crown has a column attached, over 21^{cm} in length; while another column on the same slab, and to all appearances of the same species, is over 69^{cm} long and gives no indication of proximity to either calyx or distal end.

At North Litchfield, this species was found associated with *Mariacrinus beecheri*, *Melocrinus pachydactylus*, *Cordylocrinus plumosus*, *Thysanocrinus arborescens*, *Homocrinus scoparius*, *Lepocrinites gebhardi*, and *Dalmanites* sp. The crowns are not numerous, but judging from the associated fragments of stems this spot must have been very favorable to the growth of *Melocrinus nobilissimus*. On one slab about fourteen inches long (pl. II), four crowns were found with columns belonging to forty-six more. The only other fossils on this slab are one *Conularia* and two Bryozoan fragments.

Horizon and locality.—Coeymans limestone at Litchfield and North Litchfield.

Cotypes in the American Museum of Natural History.

Melocrinus pachydactylus (Conrad). Plate I, figure 1.

Astrocrinites pachydactylus Conrad, Ann. Rept. Pal. N. Y., 1841, p. 34.—Mather, Geol. Rept. N. Y., 1843, p. 347; text-fig. 6 on p. 345.

Mariacrinus pachydactylus Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 107, pl. 3, figs. 1–4.

Mariacrinus paucidactylus Hall, ibid., p. 109, pl. 3, fig. 5.

Melocrinus pachydactylus Wachsmuth and Springer, Rev. Palæocr., Pt. II, 1881, p. 122; Proc. Phila. Acad. Nat. Sci., vol. xxxiii, 1882, p. 296; N. A. Cri. Cam., vol. i, 1897, p. 296, pl. xxiii, figs. 4 and 5; pl. xxiv, figs. 4a and 4b.

Melocrinus paucidactylus Wachsmuth and Springer, Rev. Palæocr., Pt. II, 1881, p. 122; Proc. Phila. Acad. Nat. Sci., vol. xxxiii, 1882, p. 296; N. A. Cri. Cam., vol. i, 1897, p. 296.

Actinocrinus polydactylus Bonny, Schenectady Reflector, 1835.

Although this species heretofore has been considered a rare fossil, it is now represented in the Yale University Museum by thirteen specimens. Little additional knowledge of the calyx, however, has been gained. In all cases where the distichals can be distingushed from the other plates, their number is two, instead of three. The former number agrees with all previous figures; yet, in their description, Wachsmuth and Springer make the distichals three in number.*

One of the rays, though incomplete, shows nineteen arms, which are plainly seen to be uniserial, not biserial as previously described and figured.† The actinal side of the rays and arms shows the ambulacral groove. As to the number of brachials in the successive orders of the plates of the rays, careful examination of the specimens at Yale yields results different from those reached by Wachsmuth and Springer.‡ Brachials of the fourth, fifth and sixth orders have seven plates, and the subsequent orders seem to alternate with six and seven to the

* N. Am. Cri. Cam., vol. i, p. 296, 1897.

† Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 108, pl. 3, figs. 1–3 and 4a; N. Am. Cri. Cam., Atlas, pl. xxiii, figs. 4 and 5; pl. xxiv, figs. 4a and 4b, 1897.

‡ Ibid., vol. i, p. 297.

end of the ray. In one specimen, small dome-like interpalmars show between the auxiliary arm and the tubular appendage, occupying the same position as in *M. nobilissimus*, but differing in form. Stem joints alternate in size near the calyx, but farther down the column every fourth one is larger. One individual has a stem 19^{cm} long, which makes a loop at the distal end about 2·5^{cm} in diameter. Another loop not more than 1^{cm} in diameter has two complete whorls.

M. pachydactylus is found at Jerusalem Hill with *Lepocrinites gebhardi* and many specimens of *Homocrinus scoparius;* at North Litchfield with *Mariacrinus beecheri*, *Melocrinus nobilissimus*, *Thysanocrinus arborescens*, and *Cordylocrinus plumosus.*

Wachsmuth and Springer regard *M. paucidactylus* and *M. pachydactylus* as synonyms, but give no reasons therefor. Hall's distinctions are the narrower calyx and the fewer and more distant arms of the former. The specimen figured on pl. I, fig. 1, is very narrow, proving the width of the calyx to be variable. The greater distance between the branches of the arms cannot, in itself, be considered a specific difference; and there seems to be no reason for referring these narrow specimens to another species.

Horizon and locality.—Near the base of the Coeymans limestone at Schoharie;* in the upper third of the same limestone at Jerusalem Hill and North Litchfield.

Family, *Platycrinidæ.*

Genus, *Cordylocrinus* Angelin.

Cordylocrinus plumosus (Hall). Plate III, figures 2 and 4; text-figure 3.

Platycrinus plumosus Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, pp. 113 and 148, pl. 4, figs. 1–5.

Platycrinus parvus Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 114, pl. 4, figs. 6–9.

Cordylocrinus plumosus Wachsmuth and Springer, Rev. Palaeocr., Pt. II, 1881, p. 61; Proc. Phila. Acad. Nat. Sci., vol. xxxiii, 1882, p. 235; N. Am. Cri. Cam., vol. ii, 1897, p. 737; Atlas, pl. lxxv, fig. 20.

Cordylocrinus parvus Wachsmuth and Springer, Rev. Palaeocr., Pt. II, 1881, p. 60; Proc. Phila. Acad. Nat. Sci., vol. xxxiii, 1882, p. 234; N. Am. Cri. Cam., vol. ii, 1897, p. 737.

Clematocrinus plumosus Jaekel, Zeit. d. deutsch. Geol. Gesell., Band xlix, 1897, Verhandl., p. 47.

Clematocrinus parvus Jaekel, Zeit. d. deutsch. Geol. Gesell., Band xlix, 1897, Verhandl., p. 737.

In the Yale Museum, there are many hundreds of specimens of this species; and at first glance it seemed that substantial additions could be made to the descriptions already given. Closer examination, however, revealed the fact that in only a

* Nat. Hist. N. Y., Pal., vol. iii, p. 109, 1859.

few specimens could the plates be distinguished. It also seemed that there were two species, the fossils differing so much in size, gibbosity and general appearance; but further study failed to reveal any real differences. Some of the forms have a hemispherical calyx, and arms only three or four times as long as the cup, while others have a flat cup and arms five or six times as long; and yet the plates of the calyx, the joints of the arms, the pinnules and the cirri seem to be the same in the two varieties.

In the material from North Litchfield, the lower bed has much the larger forms, all of which are compressed. The upper bed has an abundance of the smaller ones, a few of which have the calyx gibbous, not flattened. The specimens from Jerusalem Hill are uncompressed and small. Wachsmuth and Springer consider *C. parvus* the young of *C. plumosus;* and it may be that it was these small, uncompressed specimens from the upper crinoid bed that Hall had under observation when he described the former species. If this assumption can be proved, it may be well to regard *C. parvus* as a variety of *C. plumosus*, as these small forms occur at a slightly higher geological horizon.

Text-figure 3.—Anal sac of *Cordylocrinus plumosus*. *a*, right postero-lateral radial; *b*, left postero-lateral radial; *c*, first of anal series of plates. ×4.

From a study of the specimens in the Yale University Museum, the following new data may be given: In no case does the length of the column exceed once and a quarter that of the crown, which varies from 5^{mm} to 32^{mm}. A large majority of those specimens which retain the column have very many unusually long cirri.

Several of the specimens have a feature which Bather states is found in some of the Camerata, and which he explains as being due to the fusing of the joints of the arms.* In these forms the arms are composed of long joints, seemingly single, with the upper and lower surfaces parallel and horizontal. In parts of the arm, every other joint bears two pinnules on the same side of the ray. This alternation of one- and two-pinnuled joints does not extend throughout the whole length of the ray, but in places it is every third joint that has this peculiarity. Toward the base the joints are normal, that is, one-pinnuled. In his description, Hall mentions the fact that some of the joints have two pinnules; but in his figure,† he represents most

* A Treatise on Zoology, Pt. III. The Echinoderma, p. 116, 1900.
† Nat. Hist. N. Y., Pal., vol. iii, pl. 4, fig. 4, 1859.

of such joints as made of two, in this agreeing with Bather's explanation. The specimens under examination, although one is very well preserved, do not give the faintest trace of the separate joints; yet this explanation for the presence of the additional pinnules seems to be the most rational one yet offered.

Of the whole number of specimens examined, only one shows the anal tube mentioned by Hall. This tube is seen indistinctly in the photograph (pl. III, fig. 4; also text-fig. 3). The length of the tube is a little over half that of the crown.

Horizon and locality.—Upper third of the Coeymans limestone at Jerusalem Hill and at North Litchfield.

Cotypes in the American Museum of Natural History.

Order, ARTICULATA Wachsmuth and Springer.

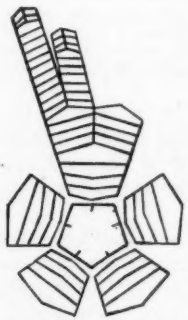
Suborder, IMPINNATA Wachsmuth and Springer.

Family, *Ichthyocrinidae* Wachsmuth and Springer.

Genus, *Ichthyocrinus* Conrad.

Ichthyocrinus schucherti n. sp. Plate III, figure 1; text-figure 4.

Specific description.—Crown, including the incurved arms, an inverted, truncated cone with straight sides. Length and breadth equal, 19^{mm}, the greatest breadth being at the point where the arms become free. Infrabasals not shown. Basals five, pentagonal. Radials five, hexagonal, wider than long. Costals three in each ray, wider than long, one hexagonal, the other two pentagonal, the upper supporting two rows of distichals, the first three ranges of which are quadrangular and the last pentangular and followed by two rows of palmars. The palmars are of different numbers in the different rays and even in different parts of the same ray. Two or three of the palmars are included in the cup. Each costal and each distichal is wider than the plate of the same order below it, but in the palmars there is a decrease in the size of the successive plates. Anal area not shown. Arms free from the second or third palmar, incurved. Each row of palmars divides at least once, making the number of branches forty. Column spreading slightly at the point of union with the crown. Joints of the column thin and equal near the calyx, alternating below, the larger ones about three times as high as the smaller. Length of column unknown.



Text-figure 4.—Diagram of *Ichthyocrinus schucherti*.

A single individual of this species was found by Professor Schuchert and was presented by him to the Yale University Museum. It differs from other species of the genus, principally in the shape of the crown, the straight sides of the cup being very characteristic. It resembles *I. lævis* more closely than any other, but differs from that species in the divisions of the rays and in the fact that the suture lines are not wavy.

Horizon and locality.—Lower third of the New Scotland limestone near Clarksville.

Holotype in the Yale University Museum.

Too little is known of the following Helderbergian crinoids to make definite statements in regard to their classification :—

Genus, *Aspidocrinus* Hall.

Aspidocrinus callosus Hall.

Aspidocrinus callosus Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 123, pl. 5, figs. 13 and 14.—Wachsmuth and Springer, Rev. Palæocr., Pt. II, 1881, p. 228 ; Proc. Phila. Acad. Nat. Sci., vol. xxxiii, 1882, p. 402.

Aspidocrinus digitatus Hall.

Aspidocrinus digitatus Hall, Nat. Hist. N. Y., Pal., vol iii, 1859, p. 123, pl. 5, figs 19 and 20.—Wachsmuth and Springer, Rev. Palæocr., Pt. II, 1881, p. 228 ; Proc. Phila. Acad. Nat. Sci., vol. xxxiii, 1882, p. 402.

Aspidocrinus scutelliformis Hall.

Aspidocrinus scutelliformis Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 122, pl. 5, figs. 15-18.—Wachsmuth and Springer, Rev. Palæocr., Pt. II, 1881, p. 228 ; Proc. Phila. Acad. Nat. Sci., vol. xxxiii, 1882, p. 402.

These species of *Aspidocrinus* present difficulties that are as yet unsolved. Hall described the forms as bases of crinoid cups, but Wachsmuth and Springer listed them doubtfully as crinoid roots. There are two reasons, at least, for thinking that they cannot be crinoid roots or basal expansions of columns. If they are basal expansions, the concave side must be the under side and this must have rested on the mud of the sea floor. One specimen of *A. scutelliformis* in the Yale University Museum has a bryozoan attached to this concave surface, proving that this surface could not have rested on the mud. If, on the other hand, these specimens represent the base of a cup, the presence of the bryozoan might be explained by supposing that its growth took place after the upper part of the dead calyx had been broken off but while the lower part still remained attached to the column.

Again, in undisputed examples of basal expansions, the lower or distal joints of the column enlarge and the segmentation of the column is continued into the upper part of the enlarged base. No such segments are visible in any of the specimens in question. In every good specimen, there is a clear-cut cir-

cular spot, generally dark-colored, which looks like the point of attachment of the column to the crown. With the exception of this spot, the cleavage lines of the calcite have obliterated all traces of organic structure.

Horizon and locality.—At the base of the Becraft limestone, or what was called the "Scutella limestone," at Clarksville, Countryman Hill and Schoharie.

Genus, *Brachiocrinus* Hall.

Brachiocrinus **(*Herpetocrinus?*)** ***nodosarius*** **Hall. Plate IV, figures 7 and 8.**

Brachiocrinus nodosarius Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 118, pl. 5, figs. 5–7, pl. 6, figs. 1–3.– Wachsmuth and Springer, Rev. Palæocr., Pt. II, 1881, p. 229; Proc. Phila. Acad. Nat. Sci., vol. xxxiii, 1882, p. 413.
Herpetocrinus nodosarius Bather, Am. Geol., vol. xvi, 1895, p. 217.

In Hall's description, these fragments of crinoids are considered as arms or parts of arms; and this opinion was also held by Wachsmuth and Springer, in 1881. In 1895, Bather brought arguments to prove that they belong to columns, not arms,* and even gave a revised diagnosis of these New York forms as *Herpetocrinus nodosarius*. That he is not so certain of this classification as the earlier paper would indicate, may be gathered from the fact that in a later reference to the fossil, he lists *Brachiocrinus* as doubtfully synonymous with *Herpetocrinus*.†

Among other points in support of his first view, he remarks that "cirri composed of thick, beadlike joints which increase in size from the base to the middle and thence diminish to the extremities," characteristic of this species, are also found in *Herpetocrinus flabelliformis*, which occurs in the uppermost beds of the Silurian of Gotland.‡

Most of the specimens in the Yale collection are so encrusted with silica that it is very difficult to get anything but general outlines; but one specimen is in fairly good condition and clearly shows the joints of the column and the cirri. The joints are slightly wedge-form and quite thin, giving to the fossil an irregular appearance, which is still further increased by the difference in the size of the joints of the cirri. The diameter of the cirri is so great that only every third or fourth joint is cirrus-bearing. The bulb-like process, varying in size and shape, is shown in several specimens at the end of the column. The question has arisen whether this bulb is at the base of the stem, or whether it is simply a thickening somewhere between the proximal and distal ends. If the latter were the case, the central canal should show at both ends of

* Am. Geol., vol. xvi, p. 213, 1895.
† A Treatise on Zoology, Pt. III. The Echinoderma, p. 146, 1900.
‡ Am. Geol., vol. xvi, pp. 215 and 216, 1895.

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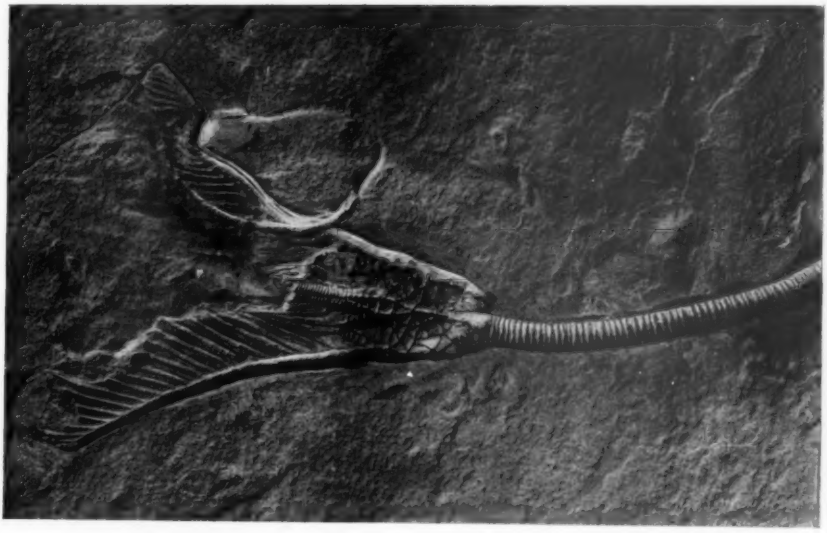

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FIGURE 1.—*Melocrinus pachydactylus.*
FIGURE 2.—*Thysanocrinus arborescens.*
FIGURE 3.—*Mariacrinus beecheri.*

Melocrinus nobilissimus.

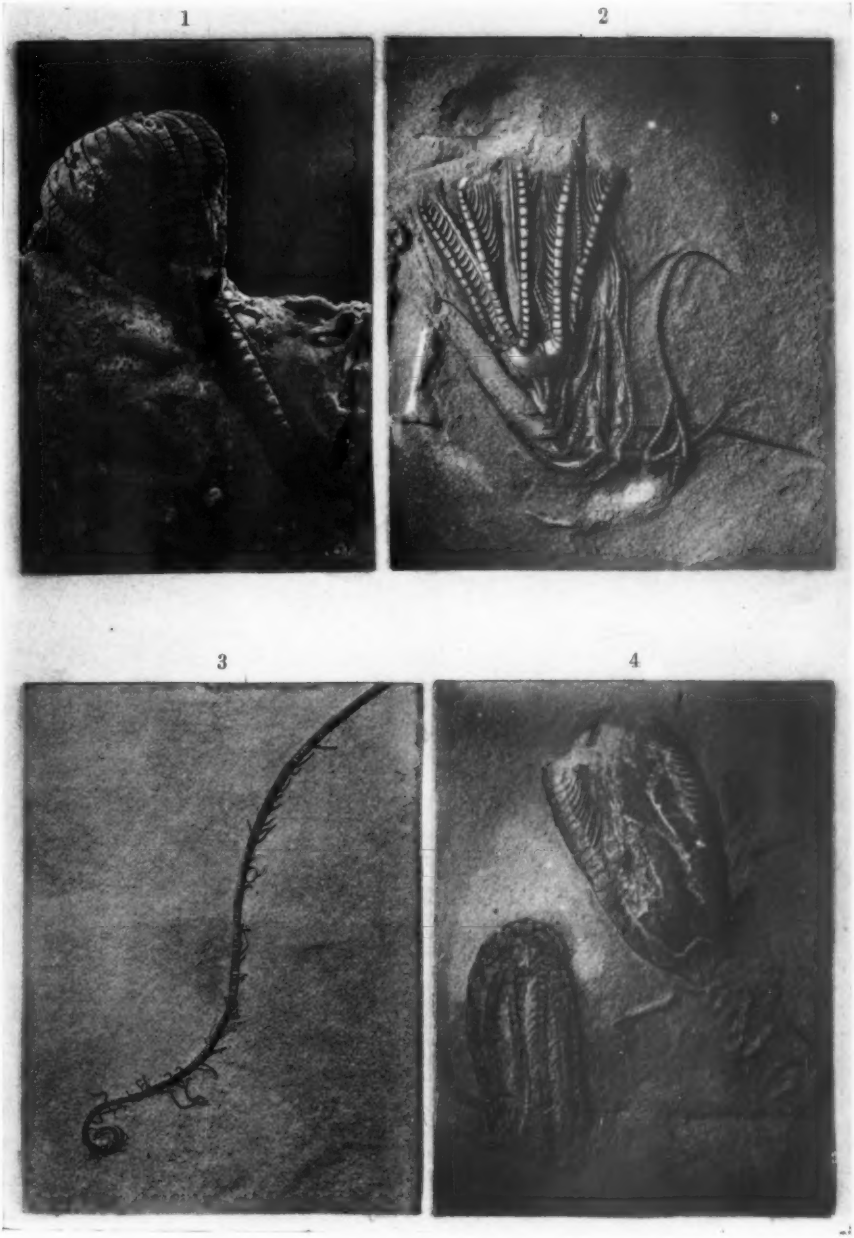
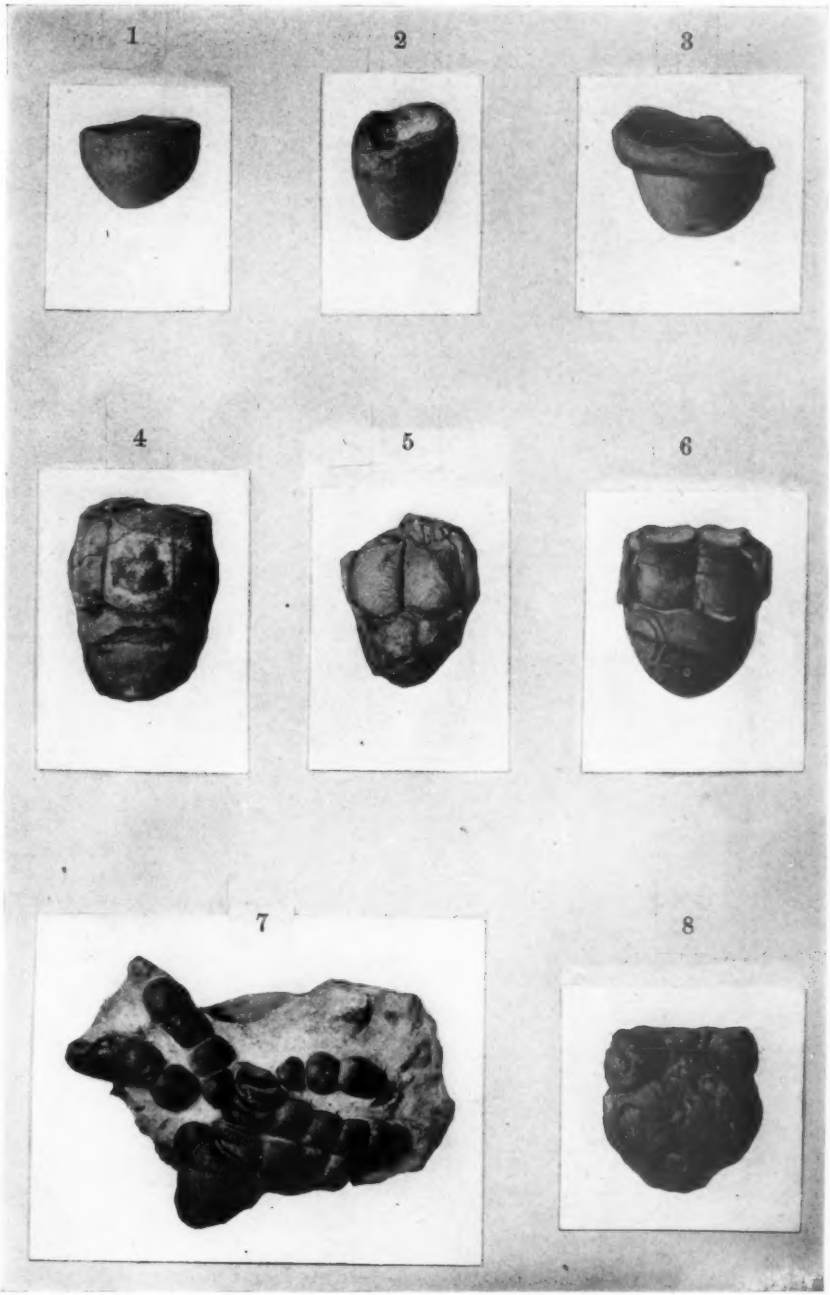


FIGURE 1.—*Ichthyocrinus schucherti.*
FIGURES 2 and 4.—*Cordylocrinus plumosus.*
FIGURE 3.—Stem of *Homocrinus scoparius.*



FIGURES 1–6.—*Edriocrinus pocilliformis.*
FIGURES 7 and 8.—*Brachiocrinus nodosarius.*

the specimens. Although one individual shows the canal very well at the distal end of the cirri and the proximal end of the stem fragment, this canal is not visible at the distal end of the bulb on any individual under observation. A small depression on one specimen looks like a cicatrix of attachment. Several individuals have the crescentic form of the joints of the column, as in *Herpetocrinus*.

Horizon and locality.—Lower part of the New Scotland limestone in the Helderberg Mountains.

Cotypes in the American Museum of Natural History and the New York State Museum.

EXPLANATIONS OF PLATES.

PLATE I.

FIGURE 1.—*Melocrinus pachydactylus.* About natural size.
FIGURE 2.—*Thysanocrinus arborescens* showing the hexagonal column and the branching of the arms. About natural size.
FIGURE 3.—*Mariacrinus beecheri* showing the thin stem joints near the crown and the separation of the two parts of the rays toward the distal end. About natural size.

PLATE II.

Slab containing stems and crowns of *Melocrinus nobilissimus.* Reduced a little more than one-half.

PLATE III.

FIGURE 1.—*Ichthyocrinus schucherti* showing the characteristic straight sides of the crown and the straight suture lines. ×2.
FIGURE 2.—*Cordylocrinus plumosus* showing the long, crowding cirri and the one- and two-pinnuled joints of the arms. ×2.
FIGURE 3.—Distal end of the stem of *Homocrinus scoparius* showing the coiling and the delicate cirri. ×2.
FIGURE 4.—*Cordylocrinus plumosus.* The upper specimen on the plate shows the anal sac. ×2.

PLATE IV.

FIGURES 1–6.—*Edriocrinus pocilliformis.* ×2.
FIGURES 1 and 2.—Simple ordinary forms, basals and infrabasals fused.
FIGURE 3.—Cup showing fused basals as a prominent ring, also cicatrix of attachment.
FIGURE 4.—Cup showing ring of basals, not protruding, and high narrow radials.
FIGURE 5.—Cup showing radials, but basals indistinguishable from infrabasals.
FIGURE 6.—Cup showing basals and infrabasals fused and radials fractured transversely.
FIGURES 7 and 8.—*Brachiocrinus nodosarius.* ×2.
FIGURE 7.—Portion of the column showing the bulb at the distal end and the beadlike cirri.
FIGURE 8.—A larger bulb with the first joints of two cirri attached.

Table of Helderbergian Crinoids.

Species with * also in the Siluric. Numbers refer to localities given below.	Coeymans.	New Scotland.	Becraft.	Location of the Type.
Aspidocrinus callosus Hall		1, 2		Holotype, Am. Mus. Nat. Hist.
" *digitatus* Hall		2		" N. Y. St. Mus.
" *scutelliformis* Hall			2, 3, 4	Cotypes, Am. Mus. Nat. Hist.
Brachiocrinus (*Herpetocrinus?*) *nodosarius* Hall		1, 2		" Am. Mus. Nat. Hist. and N. Y. St. Mus.
Cordylocrinus plumosus (Hall)	5, 7			" Am. Mus. Nat. Hist.
Coronocrinus polydactylus Hall		2		Holotype, N. Y. St. Mus.
Edriocrinus pocilliformis Hall		3, 4		Cotypes, Am. Mus. Nat. Hist.
**Homocrinus scoparius* Hall	2, 5, 6, 7			" Am. Mus. Nat. Hist.
Ichthyocrinus schucherti n. sp.		3		Holotype, Yale Univ. Mus.
Mariacrinus beecheri n. sp.	6			Cotypes, Yale Univ. Mus.
" (?) *macropetalus* (Hall), referred provisionally to *Cordylocrinus* by Wachsmuth and Springer				Cotypes, Am. Mus. Nat. Hist.
Mariacrinus plumosus Hall	7			Holotype, N. Y. St. Mus.
" *ramosus* Hall	7			" N. Y. St. Mus.
" (?) *stoloniferus* Hall		1, 2		Cotypes, Am. Mus. Nat. Hist.
Marsupiocrinus tentaculatus (Hall)		7		Holotype, Am. Mus. Nat. Hist.
Melocrinus nobilissimus (Hall)	6, 7			Cotypes, Am. Mus. Nat. Hist.
" *pachydactylus* (Conrad)	2, 5, 6			?
Platycrinus ramulosus Hall	5			? Probably occurs in Cobleskill zone of the Manlius.
Thysanocrinus arborescens n. sp.	6			Holotype, Yale Univ. Mus.

1. The Helderberg Mountains.
2. Schoharie.
3. Clarksville.
4. Countryman Hill.
5. Jerusalem Hill.
6. North Litchfield.
7. Wheelock's Hill.

Paleontological Laboratory, Yale University Museum, December, 1904.

Art. V.—*The Petrographic Province of Central Montana;* by L. V. Pirsson.

Introduction.
Definition of the province.
Consanguinity shown by minerals.
    Augite.
    Biotite.
    Hornblende.
    Feldspars.
    Absence of minerals.
Consanguinity shown in textural habit.
Chemical evidence of consanguinity.
    General law of the province.
    Application to the region.
Geographical arrangement of magmas.
    Bearing on differentiation.
Regional progression of types,

Introduction.

The fact that in certain areas of the world's surface the igneous rocks have common characteristics, which serve to ally them together and to define them from the rocks of other areas, is now well recognized by petrographers. These common features are sometimes expressed in the minerals, sometimes in the chemical composition of the magmas and sometimes in peculiarities of texture, but usually in a union of these qualities. In some cases these features are clearly marked, in others they are but slightly developed; nevertheless, like those indescribable characters which define a man as belonging to one nation rather than to another, they are easily recognized by the experienced eye.

The formulation of this principle, that the rocks of a given region may be thus genetically related, we owe to Judd,* and it has since been elaborated and applied with fruitful results to various regions by Iddings,† who developed it under the expression "*consanguinity of igneous rocks.*" Since then the idea has been applied to various regions by other petrographers; so, for example, Lacroix in a recent very interesting memoir on the alkalic rocks of northwest Madagascar, calls attention to the great belt of types rich in soda that stretches along the eastern coast of Africa.‡ Of all the various areas, however, where the consanguinity of igneous rocks has been studied and these relationships pointed out, there is probably none better known or more thoroughly investigated than that of South

* Quar. Jour. Geol. Soc., 1886, vol. xlii. p. 54.

† Origin of Igneous Rocks. Bull. Phil. Soc. Washington, xii, p. 128, 1892.

‡ Roches alcaline de Prov. Petrograph. d'Ampasindava Nouv. Arch. d. Muséum, 4me Ser., vols. i et v, 1902, 1903.

Norway, and our knowledge of this region we owe for the greatest part to the keen perception and untiring labors of Brögger, who has given the results of his work in that fine series of monographs which have become classics in the literature of petrography.

The fact that the outlying mountain groups east of the main chain of the northern Rocky Mountains are composed of rocks of a special character rich in alkalies, was pointed out by Iddings* in the work already referred to, although at that time little was known about them. Since then investigations and studies in the field and in the laboratory by a number of workers have thrown a flood of light upon this region. In the Black Hills of North Dakota the work of Caswell,† Jaggar,‡ Irving§ and the writer‖ has shown a prevalence of types rich in alkalies with soda dominating the potash.

In Montana, the most southern of the eastern outlying groups fronting the great plains, is the Crazy Mountains, some of whose interesting rocks of alkalic types are known through the researches of Wolff.¶ North of this come the various groups studied by Mr. Weed and the writer; the Castle Mountains;** the Little Belt Mountains;†† the Judith Mountains;‡‡ the Highwood Mountains;§§ the Bearpaw Mountains;‖‖ the Little Rocky Mountains¶¶ and lastly, on the border line between Canada and the United States, the Sweet Grass Hills,*** the last of the outliers. While some of these have been rather thoroughly investigated, there yet remains much to be done. The few types that have been described from the Crazy Mountains by Wolff, and its map††† showing the vast complexity of the

* Op. cit., p. 31.

† Microscopic Petrography of the Black Hills, 1876. U. S. Geog. and Geol. Surv., Rocky Mts. region. J. W. Powell in charge. Rep. on the Black Hills of Dakota, pp. 469–527, Washington, 1880.

‡ Laccoliths of the Black Hills, 21st Ann. Rep. U. S. Geol. Surv., Pt. iii, pp. 163–290, 1901.

§ Geology of the northern Black Hills. Ann. N. Y. Acad. Sci., vol. xii, No. 9, pp. 187–340, 1899.

‖ Phonolite Rocks from the Black Hills. This Journal, 3d Ser., vol xlvii, pp. 341–346, 1894.

¶ Bull. Geol. Soc. Amer., vol. iii, pp. 445–452, 1892. Bull. Harv. Mus. Comp. Zool., vol. xvi, pp. 227–233, 1893.

** Bull. No. 139, U. S. Geol. Survey, 1896.

†† 20th Ann. Rept. U. S. Geol. Surv., 1900, Pt. iii. p. 562. This Journal, 3d Ser., vol. l, pp. 467–479, 1895.

‡‡ 18th Ann. Rept. U. S. Geol. Surv., 1898, Pt. iii, p. 437–616.

§§ Bull. 237 U. S. Geol. Surv., 1905. Bull. Geol. Soc. Amer., vol. vi, pp. 389–422, 1895. This Journal, vol. ii, pp. 315–323, 1896.

‖‖ This Journal, 4th Ser., vol. i, pp. 283–301, 351–362, and vol. ii, pp. 136–148, 188–189, 1896.

¶¶ Jour. of Geol., vol. iv, pp. 339–428, 1896.

*** This Journal, 3d Ser., vol. l, pp. 309–313, 1895.

††† Little Belt Mountains Folio, Montana. U. S. Geol Surv., Geol. Atlas of U. S., No. 56, 1899.

dikes and sheets surrounding the main stocks of granular rocks, only serve to awaken general interest as to the character and relations of these rock masses, and it is to be greatly hoped that Professor Wolff will be able to continue his studies upon this interesting material and publish his results for the benefit of petrographers and for the understanding of the region. In the Bearpaw Mountains the researches of the writer upon the material collected during a hurried trip through them by Mr. Weed, which brought out such a variety of novel types of alkalic rocks, can only serve to demonstrate that this relatively large area must afford a fruitful field of study in the future; one whose complete investigation will add much to our knowledge of theoretic petrology and yield many interesting rock types.

The same must in large measure be true of the Sweet Grass Hills. The material studied by the writer gave types much like those of the Judith Mountains with hints of alkalic ones accompanying them, and the appearance of some specimens forwarded to Mr. Weed would seem to indicate that rocks of tinguoid habit occur there. Adding these facts to Dr. Dawson's* descriptions, it would seem as if they might consist largely of laccoliths probably with accompanying sheets and dikes similar in character and in rocks to those of the Judith and Little Rocky Mountains and the Black Hills.

Definition of the province.

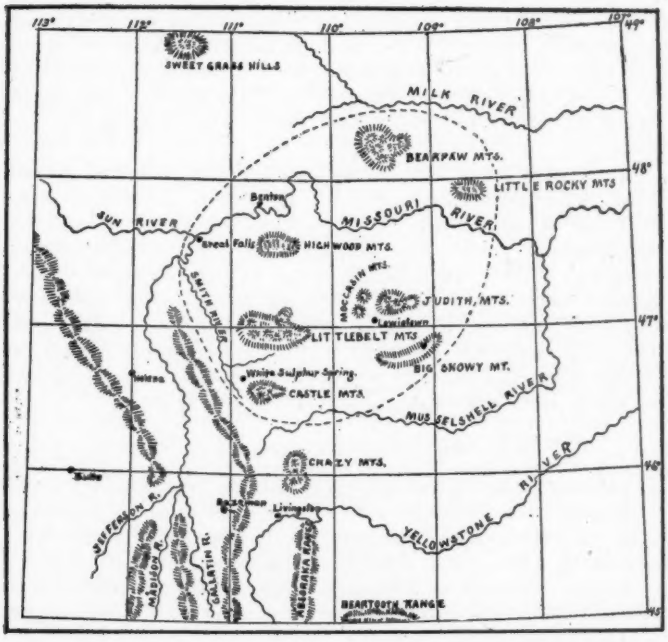
That part of this great region which has been studied by the writer, and with which he is therefore most familiar, lies in the center of Montana and embraces as its foci of igneous activity the Castle, Little Belt, Judith, Highwood, Bearpaw and Little Rocky Mountains. Since the general reader cannot be expected to be familiar with the geography of this region and the disposition of these groups, their arrangement with respect to one another and to the main chains of the Rocky Mountains is shown on the accompanying sketch map. It will there be seen that they lie in a roughly oval area stretching from the northeast towards the southwest, about 150 miles long by about 100 broad, in the middle of Montana and shown on the map by the dotted line. It is this region which it is here proposed to define as the petrographic province of central Montana; the consanguinity and general family relations of whose rocks it is intended to describe.

This paper then may be considered as a general summation along the line just mentioned of the work of the writer on these different mountain groups, presenting the broad petrologic features they possess in common. For the separate

* Rep. Canadian Geol. Surv., 1882-4, Pt. C, pp. 16 and 45.

details the reader is referred to the series of memoirs upon them whose list is given upon a foregoing page.

The evidences of consanguinity are to be seen in two ways, in certain mineral peculiarities and in the chemical composition of the magmas, the first being dependent upon the second in conjunction with the physical conditions attendant upon crystallization.



Map of Central Montana showing arrangement of mountain groups in petrographic province.

Consanguinity shown by minerals.

Augite.—One of the most marked features in regard to the mineral composition of this composite geographical rock family is to be seen in the augite. This has been already pointed out by Iddings,* but its application to this province is worthy of special mention.

The augite is of a distinct green color, very rarely pleochroic. It varies from very pale to a deep green. Brown or purplish augites are rare. They do occur in some of the lamprophyric dikes and flows but are exceptional, so that in a great preponderance of the rocks the green augite distinctly rules. Moreover this applies through the whole series from

* Op. cit., p. 131.

the most salic to the most femic types, the depth of color usually increasing somewhat towards the ferromagnesian pole. It is commonly supposed that the purplish color of augite is due to the titanic oxide it contains; and while this perhaps is true, it should nevertheless be pointed out that one of these green pyroxenes from the shonkinite of Square Butte, analyzed by the writer, contained over a half per cent of titanic oxide. It is also to be noted that titanic oxide occurs in all of these rocks, gradually increasing with the iron towards the ferromagnesian pole, yet the rocks towards this end still have the strong green color in the pyroxene. This is especially noticeable in the shonkinites of Yogo peak in the Little Belts, in the various occurrences in the Highwoods and in the Beaver stock and elsewhere in the Bearpaws, the TiO_2 ranging from 0·75 to 1·50 per cent, the silica falling as low as 46 per cent in the latter case. The occurrence of this green augite through the whole series is more strongly marked in the Highwoods than elsewhere and this local peculiarity did not escape Lindgren's notice and he makes especial mention of it,* not only for the Highwoods but for the other groups of the region with which he was acquainted. There is no notable exception to this rule in any of the Highwood rocks numbering several hundred occurrences studied by the writer, no matter how salic or femic the types may be.

This green augite is a marked feature then of this petrographic province, and in this respect it appears to differ from many other well-marked provinces of alkalic rocks. In the exceptional cases mentioned above, the augite is pale brown, strong purplish colors not having been noted, so far as the writer can recall, in the whole province.

In the salic rocks rich in alkalies, aegirite-augite appears: this is a marked feature of those of tinguoid habit; aegirite itself is rare. This seems to be due to the dominance of potash over soda, as will be shown in the discussion of the chemical peculiarities of the province. It is possible that the characters of the pyroxene, including its green color and non-pleochroism, are also due to this general chemical character of the magmas.

Biotite.—Throughout the province the biotites are the brown, strongly pleochroic variety—ordinary biotite. The red-brown biotites of the theralite rocks found in the Crazy Mountains to the southward do not occur, nor the pale phlogopites of the rocks rich in potash of the Leucite Hills in Wyoming as described by Zirkel† and Cross.‡ In some exceptional

* 10th Census United States, vol. xv, p. 726, 1886.

† Micro. Petrog. 40th Parallel Surv., vol. vi, p. 261.

‡ Igneous Rocks of the Leucite Hills and Pilot Butte, Wyoming; this Journal, vol. iv, 1897, p. 120.

cases of the lamprophyric dike rocks the biotites have darker borders, otherwise they are very uniform in all classes alike.

Hornblende.—This mineral is, comparatively speaking, of limited occurrence. It is found in an alkalic type in Square Butte syenite (pulaskose), and in the trachyandesite (adamellose) flow on North Willow creek in the Highwoods, and in some of the porphyries composing the laccoliths in the various mountain groups and in vogesite dikes in the Castle and Little Belt Mountains; but, with these exceptions, when it occurs it is clearly uralitic after augite. In this province augite rules in the vast majority of cases and even in the quartzose rocks (quardofelic types) it appears rather than hornblende.

Feldspars.—It cannot be said that there is any specially marked evidence of consanguinity to be seen in these minerals so far as the author is able to detect. They do not present, for instance, any such remarkable features as those seen in the feldspars of the alkalic rocks of south Norway, shown in their greatest development in the phenocrysts of the rhombic porphyries. It is to be noted, however, that on account of the tendency for potash to dominate soda in the magmas, that orthoclase or soda-orthoclase is commonly the chief feldspar. Albite is of rare occurrence, even in the strongly alkalic types free from plagioclase, the one instance which is an exception to this—the porphyry of Lookout Butte* in the Little Rockies—being a notable exception. On the other hand, it is an interesting fact that in spite of the strong predominance of potash feldspar in so many occurrences of all kinds, microcline may be said to be absolutely wanting in the province. It is probably due to the comparatively recent and hypabyssal character of these rocks and the fact that they have not been subjected to dynamic pressures.

Absence of minerals.—The characters of a petrographic province are shown as much by the absence of some minerals as by the presence of others. In this one it is shown by the rarity or absence of minerals caused by the groups of rare earths—as they have, somewhat infelicitously, been called,—that is minerals marked by the presence of zirconia, thoria, cerium, lanthanum, didymium, columbic oxide, etc., etc. Even titanite is a rather rare mineral and zircon uncommon. Experience would seem to show that it is chiefly magmas rich in soda which these oxides accompany and that the potassic dominance in the magmas of the central Montana province tends to exclude them and to produce rocks lacking in the interesting minerals they give rise to.

* Jour. of Geol., vol. iv, p. 422, 1896.

Consanguinity shown in textural habit.

In some cases the consanguinity of the rock family is shown in the repetition of certain textural habits. Thus the pseudo-leucite basalts of both the Highwoods and the Bearpaws closely resemble each other and both of them differ in habit from the leucitic rocks of other regions, from those of Italy for example. A most marked instance is also seen in the minettes of Highwood type (phyro-biotitic-cascadose). These occur not only in the Highwoods but thirty miles to the north-east on the Missouri River Mr. Weed collected similar rocks and they occur doubtless in the Bearpaw Mountains.* One of these from the Missouri River so exactly resembles the occurrence on Williams Creek on the south slope of the Highwoods and described in the memoir on the Highwood rocks† that hand specimens of the two cannot be distinguished from one another. So too, while each occurrence of shonkinite in the region, in the Little Belts, the Highwoods and the Bearpaw has its own peculiarities, yet taken together they form in sum total a well marked family group.

In the salic, feldspathic types, on account of their simpler composition these evidences of family relationship are less distinctly marked, and yet in the porphyries composing the laccoliths in all the groups of the province, there appears to be a tendency towards the repetition of a type with a certain textural habit difficult to describe but easily recognizable. It appears to be largely conditioned by a certain abundance, size and disposition of phenocrysts. There are many wide exceptions and variations of this, nevertheless the rule holds.

Chemical evidences of consanguinity.

The strongest evidences which show that the rocks of these various groups belong to a common family are to be found in comparing their chemical compositions. For this purpose a sufficient number of analyses are available for the Castle, Little Belt, and Highwood Mountains. For the Bearpaws there are enough to show the general character of the magmas, though more would be desirable. For the Judith and Little Rocky Mountains there is only one for each, but the general similarity of the types, shown by their petrographic study, is sufficient to indicate that they must agree in essential chemical characters, and as the rocks are of very similar nature and of simple types the two analyses must supplement each other fairly well. The Moccasin Mountains, which are two compound laccoliths, are practically a part of the Judith Mountains, and their rocks,

* Judging from Dawson's description (op. cit., p. 46) it seems probable that the same type also occurs in the Sweet Grass Hills.

† Igneous Rocks of the Highwood Mts., Bull. No. 237, U. S. Geol. Surv., 1904, p. 142.

as shown by Lindgren's* brief description and by specimens collected by Mr. Weed, are mainly composed of feldspar porphyries similar to those of the Judith Mountains.

In all 58 analyses have been made and published of rocks of this province, 15 by H. N. Stokes, 12 by W. F. Hillebrand, and one by W. H. Melville in the laboratory of the United States Geological Survey; 16 by the author and 14 under his direction by Messrs. H. W. Foote and E. B. Hurlburt in the laboratories of the Sheffield Scientific School in New Haven. It is not

Castle Mountains Magmas.

	1	2	3	4	5	6	7
SiO_2	74·9	65·9	61·9	56·8	46·5	45·1	42·5
Al_2O_3	13·6	16·8	17·3	18·3	10·5	15·4	12·0
Fe_2O_3	·7	1·6	2·3	1·6	4·4	2·8	3·2
FeO	·5	1·2	2·4	5·6	7·8	5·6	5·3
MgO	tr	1·5	1·8	3·6	10·6	6·5	12·4
CaO	·6	2·6	3·2	5·3	9·5	8·8	12·1
Na_2O	4·2	4·7	5·2	4·3	3·1	2·8	1·2
K_2O	4·6	3·1	3·8	3·3	1·5	2·8	2·7

Little Belt Magmas.

	8	9	10	11	12	13	14	15	16	17	18
SiO_2	73·1	69·7	68·6	64·9	61·6	62·2	54·4	52·3	48·3	48·4	49·0
Al_2O_3	14·3	15·0	16·1	15·4	15·1	15·8	14·3	14·0	13·3	11·6	12·3
Fe_2O_3	·5	·8	2·2	2·0	2·0	1·8	3·3	2·8	4·4	4·1	2·9
FeO	·3	·3	·4	1·6	2·2	2·4	4·1	4·4	3·2	3·6	5·8
MgO	·2	·7	·7	2·6	3·7	3·5	6·1	8·2	8·4	12·5	9·2
CaO	1·1	2·1	1·4	3·1	4·6	4·1	7·7	7·1	9·9	7·6	9·6
Na_2O	3·4	3·4	4·4	4·2	4·3	3·9	3·4	2·8	3·3	4·1	2·2
K_2O	4·9	4·4	4·9	3·9	4·5	3·9	4·2	3·9	3·0	3·2	5·0

Highwood Magmas.

	19	20	21	22	23	24	25	26	27	28	29	30	31
SiO_2	65·5	59·2	58·0	57·2	56·4	55·2	51·9	51·7	49·6	47·8	48·0	46·0	46·1
Al_2O_3	17·8	13·8	17·2	18·5	20·1	18·3	15·8	14·5	14·5	13·6	13·3	12·2	10·0
Fe_2O_3	·7	5·5	2·5	3·6	1·3	4·9	4·1	5·1	3·5	4·7	4·1	3·9	3·2
FeO	1·1	1·4	1·2	1·1	4·4	2·1	3·2	3·6	5·5	4·5	4·2	4·6	5·6
MgO	1·0	4·8	1·8	·7	·6	1·8	3·5	4·6	6·2	7·5	7·0	10·4	14·7
CaO	1·9	5·6	3·5	2·3	2·1	3·6	6·0	7·0	9·0	8·9	9·3	9·0	10·5
Na_2O	5·5	3·1	3·4	4·5	5·6	4·0	3·4	2·9	3·5	4·4	3·5	2·4	1·3
K_2O	5·6	4·2	10·1	8·6	7·1	6·4	7·7	7·6	5·6	3·2	5·0	5·8	5·1

Bearpaw Magmas. *Little Rocky and Judith Magmas*

	32	33	34	35	36	37	38	39	40
SiO_2	66·2	68·3	57·5	52·8	51·9	50·0	46·5	68·7	57·6
Al_2O_3	16·2	15·3	15·4	15·7	20·3	9·9	11·8	18·3	17·5
Fe_2O_3	2·0	1·9	4·9	3·1	3·6	3·5	7·6	·6	3·5
FeO	·2	·8	·9	4·8	1·2	5·0	4·4	·1	1·2
MgO	·8	·5	1·4	5·0	·2	11·9	4·7	·1	.2
CaO	1·3	·9	2·6	7·6	1·6	8·3	7·4	1·0	1·4
Na_2O	6·5	5·5	5·5	3·6	8·5	2·4	2·4	4·9	5·8
K_2O	5·8	5·6	9·4	4·8	9·8	5·0	8·7	4·7	9.2

* This Journal, 3d Ser., vol. xlv, pp. 286–297, 1893.

worth while, however, to give all these analyses,* for some of them from a given area, for our purposes, would be merely repetitions of one another, and in this case only one is selected to represent this variety of magma. Only the essential elements are given and consequently the summations are omitted. In examining these tables of analyses the first thing that is evident is that in general, high silica, alumina and alkalies go together and are opposed to lime, iron and magnesia. This is of course merely a general truth applicable to all igneous rocks and not a special character of the province. The special and most obvious feature which distinguishes this district is in the relation of alkalies to one another and to silica. The potash dominates over the soda.

General law of the province.—Definitely stated it is this; *The petrographic province of central Montana is characterized by the fact that in the most siliceous magmas the percentages of potash and soda are about equal; with decreasing silica and increasing lime, iron and magnesia, the potash relatively increases over the soda, until in the least siliceous magmas it strongly dominates.* An inspection of the tables will show that there are but a few partial exceptions to this law in the 40 analyses given, and since all which are exceptions are given, the 18 omitted analyses would merely add the weight of additional figures to the truth of the law.

Application to the region.—It will be of interest now to examine this more in detail with respect to the various mountain groups. The Castle Mountains lie on the extreme southern border of the province; their next neighbor to the south is the Crazy Mountains group, and an examination of analyses from that district† shows that in the magmas soda strongly dominates the potash throughout the series. The writer has already shown‡ that the general Castle magma was one of a very salic character, in fact that of a granite, and that femic rocks play but a small role. Thus in the siliceous types we see the influence of the nearby Crazy Mountains' magma; the soda here slightly dominates the potash; we are on the edge of the province and the rocks are transitional. The relation to it is seen however in the most femic type, since here potash dominates the soda. As we go northward from here into the province the Little Belt rocks came next and its characters become more evident. In percentages potash begins to rule even in the siliceous types and in the extreme femic types this peculiarity is strongly marked. Only two exceptions are noted, both of which are given and both of which are narrow dikes. Their exceptional

* They may be found in the works previously cited.

† Bull. U. S. Geol. Surv. 168, pp. 120–124, 1900.

‡ Geology of the Castle Mountain Mining District, Bull. U. S. Geol. Surv. 139, p. 138.

position in the Little Belt series has been already discussed.* In the siliceous rocks the dominance of potash as one goes toward the center of the province sometimes expresses itself more strongly; thus in the granite porphyry of Wolf Butte on the extreme northern edge of the Little Belts the relations are $K_2O : Na_2O = 4{\cdot}4 : 3{\cdot}3$, as shown in an analysis not quoted above.

Next north beyond the Little Belts and near the center of the province are the Highwoods, and here its characters reach their highest development. The most siliceous type has equal percentages of soda and potash; there is only one occurrence, the syenite of Highwood peak; in the others the potash strongly dominates, increasing towards the femic end until in missourite it is 4 to 1. There is only one exception in this group which has been found, No. 28 in the table. It is the analcite basalt of Highwood Gap, occurring in narrow dikes.

The general line through the province to the northward now bends to the east toward the Bearpaws. Between the Bearpaws and the Highwoods there is an occurrence of igneous rocks in small stocks and dikes on the Missouri river. They have not yet been throughly investigated, but the study of sections made from specimens collected by Mr. Weed shows them of femic types like those occurring in the Highwoods. They are in fact largely minettes of Highwood type, as previously mentioned, and all their characters show that they closely conform to the general law and that potash rules.

Next beyond these come the Bearpaws, in which the general law of the province strictly holds. It is to be noted that towards the southern side the rocks are femic, and as we pass through the group we find on the northeast, on the edge of the province, salic (quardofelic) types occurring in laccoliths again as in Eagle Butte, the analysis of whose rock is shown in No. 32. Again here as on the southern edge the soda rises until it slightly exceeds potash.

Southeast of here, defining the edge of the province in that direction, are the Little Rockies, another laccolithic intrusion of salic types. There is some variation and the rocks pass into a tinguaitic phase. Exactly of the same character are the Judith Mountains; also a boundary group on the edge of the province, of salic types running into tinguaites. There is as yet only one analysis from each of these groups, one of a granite porphyry from the Little Rockies No. 39 and one of a tinguaite (judithose) from the Judith Mountains. Thus they supplement each other and the general law holds true, the potash increasing as the silica falls. It is also to be noted that in neither of these boundary groups do any femic types occur.

* Petrography of the Little Belt Mts., 20th Ann. Rep. U. S. Geol. Surv., Pt. iii, p. 576.

So far as is known, the Sweet Grass Hills off to the northwest agree with the last two groups, but the absolute confirmation of this must await future exploration and study. Moreover they are somewhat outside of the general area under discussion. In this connection however there might be mentioned Big Snowy Mountain, south of the Judith Mountains. This is evidently a large laccolithic uplift, and from the Judith Mountains the heavy white Carboniferous limestones dipping away from it are clearly seen. Intelligent mining prospectors, who have searched the mountain for ore deposits, have assured me that it is all limestone on top and that no porphyry is exposed. The laccolithic roof has evidently not yet been eroded away, but considering all the facts of structure and occurrence in this province, there can scarcely be reasonable doubt that a concealed body of feldspathic porphyry lies underneath the limestone dome.

Geographical Arrangement of Magmas.

From what has been already said, it is now evident that there is a rather orderly arrangement of magmas in the province. Around the outer edge they tend to be strongly siliceous, low in lime, iron and magnesia, and with the percentages of soda about equal to those of potash, and these magmas have usually marked their upward movement and intrusion by the formation of laccoliths. One can say in truth that the boundary of the province on the south, southeast, east, north and if it be extended to include the Sweet Grass Hills, on the northwest, is defined by laccoliths or groups of laccoliths of a rather definite type of magma. On the west the boundary is not yet well known and is perhaps not so clearly defined. At all events, in this direction it is eventually cut off by the main ranges of the Rocky Mountains, whose magmas, so far as we know them, are of a quite different character, belonging in fact to the granite-diorite series whose surface equivalents are rhyolites, andesites and basalts.

On the border line of the province thus defined femic types are rare or wanting. When they appear, however, they tend to assume the regional character and potash rises. As we approach the center of the province they become more numerous and of larger volume and as silica sinks the potash rises. This is shown by the occurrences of monzonite and shonkinite in the Little Belts and on its northern edge. Finally, in the central portion of the province in the Highwoods, on the Missouri river and in part of the Bearpaws the magmas are distinctly femic and rocks rich in ferro-magnesium components form the largest masses, are most numerous in occurrence and distinctly rule. There is still a recurrence of salic types, but they are of small volume and of diminished importance.

This arrangement of magmas over the region is of course not so well displayed as if there had been outbreaks of lava and igneous intrusions in every ten square miles of it and all conforming to the rule, but it is believed by the writer that one who reads carefully the facts previously stated and studies the map must be struck with the disposition of the magmas about a common center as shown in the mountain groups. It does not appear as if this could be mere chance; on the contrary, it certainly seems to point to an orderly arrangement of things according to some definite cause, whether we are able to discover the latter or not.

Bearing on Differentiation.—It will be noticed that this arrangement is contrary to what obtains in most cases of local differentiation such as those of Yogo and Bearpaw peaks and Square Butte in this province, in which the border zones are femic with a concentration of the salic components towards the center. Washington* has shown that at Magnet Cove the contrary is the case, the outer zone being more salic and the inner part of strongly femic types. An instance of this also occurs in this province in the "diorite" intrusion of Castle Mountain near Blackhawk,† which at the center is a monzonoid rock with 56 per cent of silica and grows steadily more siliceous towards the periphery until it becomes a quartzose porphyritic type. Other examples are described by Brögger‡ in Norway and Ramsay and Hackmann§ in Lapland.

Washington in discussing these cases‖ is inclined to view them as results of processes of solution and crystallization in which the magma, composed of silica, alumina and alkalies, is the solvent, the others being the solutes, and the solvent being in excess tends to crystallize first at the outer margins. This might explain such cases of *local* differentiation as are seen in laccoliths like Square Butte, but it is clear that it could not be applied to whole regions. For granting for the moment that a parent body of homogeneous magma can form diverse smaller bodies by some process, it could not do so over wide areas by one of solidification; the facts demand that the cleaved products should remain liquid though these secondary bodies, after intrusion into place, might yield diverse products by crystallization. The writer is not inclined to believe, on the other hand, that pure molecular flow, which Becker¶ has shown must take place with great and increasing slowness, can be a sufficient

* Igneous Complex of Magnet Cove, Bull. Geol. Soc. Amer., vol. xi, p. 407. 1900.

† Bull. 139, U. S. Geol. Surv., pp. 134 and 140, 1896.

‡ Brögger: Zeit. f. Kryst., vol. xvi, 1890, p. 45.

§ Ramsay and Hackmann: Fennia, vol. xi, No. 2, 1894.

‖ Loc. cit., p. 408.

¶ This Journal, vol. iii. p. 21, 1897.

modus operandi on a vast scale. But within limits and with sufficient time it may be a factor of importance, and combined with convection currents and forced movements on a small scale due to the passage of heated gases, and on a large one to dynamic movements of the crust, a variety of agencies may be brought into play which may be sufficient to render a body of homogeneous magma, even if of considerable size, quite diverse in its parts. And it is to be clearly noted that this is quite independent of the question as to whether the magma shell of the molten earth (supposing there ever was such a thing) was ever homogeneous or not. This is purely an academic question and may always, as at present, remain a matter of mere speculation. Whether it was or not, the magmas underlying the crust are different now in different regions, and this is the basic fact with which the petrographer has to concern himself.

On the other hand, it is the writer's belief that it would be unreasonable to throw away such indications as those afforded above, that the distribution and occurrence of igneous rocks are not due to mere chance; to deny they are governed like other things in nature by definite laws and processes; to affirm that they are caused by mere haphazard heterogeneity of the underlying magma, and to thus dispose of the subject by relegating it to chaos.

In regard to *local* as distinguished from *regional* differentiation, we know something of the conditions and occurrences most favorable for its operation of the magmas in which it is most likely to occur and to predict some of the probable results of its operation. But in regard to the latter it does not seem to the writer quite reasonable to assume that agencies and processes that would be operative on a small scale would be necessarily applicable to vast bodies of magma underlying great regions. The writer has already discussed this phase of the subject in another place and it is not necessary to repeat it here.* But in the writings and speculations of many petrographers a good deal of confusion on this subject appears and the differentiation of huge "magma basins" presumably covering hundreds and even thousands of square miles, is discussed in the same terms and with appeal to the same supposed agencies as has produced visible results in a single dike, laccolith or other relatively small rock body. In the writer's opinion this is wrong and will only tend to throw discredit upon what has so far been produced that is of real value. It must be confessed that at the present time so little is known and so much remains to be discovered that any attempt, from the

*Igneous Rocks of the Highwood Mountains, Bull. 237 U. S. Geol. Surv., p. 183.

data in hand, to solve the problem of general differentiation over wide regions must be a mere speculation. While the physical chemist therefore is attacking the problem on one side, it remains for the petrographer, on the other, to gather data regarding the occurrences of igneous rocks and their interrelationships and characters over definite areas, and the present article can be considered as a contribution towards this end.

The Regional Progression of Types.

It is desired to call attention here to a phase of the occurrence of rock types in the province in the hope that petrographers may observe if it is of general application in different petrographic provinces.

In lieu of a better name it may be called the *regional progression of types*, and the idea involved in this term is as follows: while in a given province there are certain family characters serving to bind the various rock types into one clan, yet from place to place within its limits the magmas may vary greatly from each other, and there may be, as in the Montana province, a number of centers with complexes of their own. It is so to speak that the clan is made up of a number of families each of which consists of individuals. In traversing the area from one family to another, the observer will note that certain types which are rare or sporadic in the first will become numerous or even dominating ones in the second. Long before the second family is reached its types begin to appear, and as the area is approached they are likely to become more numerous, then attain their greatest frequency and die away beyond. Thus there is an overlapping of types and the rare one of a given center of igneous rocks becomes the common one of a neighboring center. It of course depends upon the gradual change in the character of the magmas.

Some instances of this which have been observed in this province are as follows. In the Castle Mountains a single sporadic case of a monchiquoid rock was observed.* Going northward into the Little Belts they begin to be more common, and the author has described them under the name of "analcite basalts,"† while still farther to the northward in the Highwoods these are exceedingly common rocks. They occur for the greater part in dikes but in the Highwoods in flows also. In the midst of the Castle rocks this type appeared out of place when considered only by itself, but if we consider it not as a member of the Castle family, but of the central Montana clan, its occurrence falls into order.

*Bull. 139 U. S. Geol. Surv., pp. 68 and 114, 1896.

† Petrog. Little Belt Mts., 20th Ann. Rep. U. S. Geol. Surv., Pt. iii, p. 543, 1900.

Again, in the Castle district the stock at Blackhawk described under the name of "diorite" has its central portion developed as a monzonoid facies, as may readily be seen by reference to its description and analysis.* In the Little Belts to the north monzonite occurs in a considerable mass at Yogo Peak,† and in the Highwoods‡ and Bearpaws§ it is a prominent type.

Or again, shonkinitic facies of rock masses are found at Yogo Peak in the Little Belts and in the stock at the head of Beaver Creek in the Bearpaws, while in the Highwoods this rock is the common type and found in numerous masses.

So also rocks of tinguoid habit do not occur at all in Castle Mountain or in the Little Belts in the southern part of the province. They first begin to appear in the Highwoods in the middle part; here they are rare, only a few occurrences being noted, but in the Judith,‖ Little Rocky¶ and Bearpaw** Mountains which define the northern part of the province they are very common rocks.

Other instances might be cited but these are sufficient to indicate the idea involved. It is in intrusive rocks of various kinds of occurrence, and perhaps more noticeably in dikes, that this progression of types is seen. The extrusive rocks do not occur so generally in this province that it may be observed among them.

It would be a matter of interest to know if this progression of types is a peculiarity confined to this province and occasioned by the local distribution of magmas or whether it is of more general application. The writer has observed indications of it in other places, as, for instance, in central New Hampshire, where at Red Hill and Mount Belknap centers of alkalic magmas occur. These are indicated at long distances by sporadic dikes of bostonoid and camptonoid habits, the latter becoming very numerous at the actual centers. But outside of the central Montana area the writer has not that intimate acquaintance with other broad petrographic provinces which is necessary to be able to apply this idea to them, and it must be left to others. It would seem as if south Norway and central Italy and perhaps the Bohemian Mittelgebirge, which is being so ably investigated by Hibsch, might afford good examples.

Sheffield Scientific School of Yale University,
New Haven, Conn., December, 1904.

* Bull. 139, p. 89.
† Petrog. Little Belt Mts. p. 475.
‡ Bull. 237, p. 76.
§ This Journal, vol. i, p. 355, 1896.
‖ 18th Ann. Rep. U. S. Geol. Surv. Pt. iii, p. 566, 1898.
¶ Journal Geol., vol. iv. p. 419, 1896.
** This Journal, vol. ii, p. 189, 1896.

ART. VI.—*Croomia pauciflora* Torr. An anatomical study; by THEO. HOLM. (With one figure in the text drawn by the author.)

MANY years ago *Croomia* was considered a member of the *Berberidaceæ* and an ally of *Berberis*, *Caulophyllum*, *Diphylleia*, *Jeffersonia* and *Podophyllum*,* with the admission, however, that the examination of a single seed did not disclose whether the plant was dicotyledonous or not, and that the affinity in either case remained obscure. Several years later the mistake was corrected by Gray himself and the genus referred to the *Roxburghiaceæ*.† Besides the American species there is another one in Japan: *C. Japonica* Mig., but these two are the only ones, known so far, of this singular genus. The monotypic *Stichoneuron* and the small genus *Stemona* Lour. (*Roxburghia* Banks) are with *Croomia* the only representatives known of the order. Habitually these genera are quite distinct, *Stemona* being a tall climber, the others low herbs; the floral structures have been carefully described by Gray, Bentham and Hooker, and Engler and Prantl. A more detailed account of the morphology of the flower as well as the anatomy of the vegetative organs of some species of *Stemona* has been given by Mr. Lachner-Sandoval.‡ In regard to *Croomia* Gray pointed out some few peculiarities in the stem-structure, sufficient to prove that its systematic position would have to be sought among the *Monocotyledones*, but otherwise the genus has not been studied from this particular point of view.

Having received some fresh material from Alabama, we have examined the internal structure of the vegetative organs of *Croomia*, and the following notes may be considered as supplemental to those of Mr. Lachner-Sandoval for illustrating the comparative anatomy of this peculiar little order. A few remarks upon the rhizome may, also, be inserted at this place.

As stated above, *Croomia pauciflora* is a low herb with a few green leaves and two- or three-flowered inflorescences near the apex of the single stem. The rhizome represents a sympodium; it is slender, horizontally creeping with stretched internodes and scale-like, membranaceous leaves. The terminal bud produces the aerial, flower-bearing stem surrounded at the base by three scale-like leaves, while a bud from the axil of the lowermost of these pushes out into a horizontal, subterranean branch, which continues the direction and growth of

* Gray, Asa: Genera floræ Americæ bor.-orient. ill. Vol. i, 1848, p. 90.

† Same: On the genus *Croomia*, and its place in the natural system. (Mem. Amer. Acad. Sc., Ser. 2, vol. vi, 1859, p. 453, plate 31.)

‡ Beitrag zur Kenntniss der Gattung *Roxburghia*. (Botan. Centralb., vol. 1, 1892, p. 65.

the mother-rhizome. Dormant buds may be observed in the axils of some of the leaves of the horizontal portion of the rhizome. The roots are white, somewhat fleshy and sparingly ramified; they develop mostly below the nodes or, sometimes, a little above these.

In the Japanese species *C. Japonica* Mig. the habit of the plant is the same, but the flowers are single in the axils of the leaves, and the rhizome has no stretched internodes.

The internal structure of the vegetative organs of our species of *Croomia* shows several points of interest, when compared with the allied orders, and we will begin with the roots.

The roots.

The secondary roots are storage-roots with no contractile power; they are nearly glabrous and the thin-walled epidermis persists covering directly the cortical parenchyma, no hypoderm being developed. The cortex consists of about fifteen layers of thin-walled, starch-bearing cells, constituting a rather compact tissue. There is an endodermis of exceedingly small cells with thin walls and the Casparyan spots barely visible; it surrounds a continuous similarly thin-walled pericambium. Inside this are seven narrow rays of hadrome with one to two protohadrome vessels and about twenty, much wider, around a narrow central group of moderately thickened conjunctive tissue.

The thin, lateral roots show a like structure, but the cortex contains no starch and the endodermis is large-celled with the spots plainly visible; these roots were diarchic and the position of the protohadrome vessels was like that in the mother-root, inside the pericambium.

The rhizome.

When we examine one of the stretched, horizontal internodes we notice a smooth cuticle and an epidermis with the outer cell-walls moderately thickened. The cortex consists of about twenty-five layers, of which the peripheral two or three are collenchymatic, the others thin-walled and starch-bearing. No endodermis was to be observed, and the mestome-bundles possess only a weak support of stereome, which does not form a continuous ring around these. It is merely represented by a few, one to two, layers on the inner face of the mestome-bundles or on the sides of these; on the leptome-side this tissue is, also, poorly developed, sometimes entirely wanting.

The structure of the mestome-bundles is very irregular. They are apparently arranged in one or two circles, but several of these having fused together so as to form several groups of leptome and hadrome in immediate connection with each other, their number or real position could not be ascertained. As will be seen later, the mestome-bundles of the stem above

ground are leptocentric, and this structure is, also, to some extent to be observed in the rhizome, but much less regularly; the following variations were noticed. A few were collateral with the leptome and hadrome radially opposite each other and supported by stereome on both faces, the outer and the inner. Or the leptome was found to be surrounded by the vessels on the sides, and these bordering again on other groups of leptome with or without some support of stereome; in others the leptome constituted but one group with some vessels on the sides, while inwards it was separated from the pith by layers of stereome. Near the periphery of the cortex were observed two isolated, collateral and, in transverse section, orbicular mestome-bundles.

The central portion of the rhizome is occupied by a thin-walled, starch-bearing, solid pith.

A much more regular structure exists in the short, vertical internode below the uppermost of the three scale-like leaves which surround the base of the flowering stem. In this internode the fourteen mestome-bundles are located in an almost regular circle; nine of these are leptocentric and much larger than the remaining five, which are collateral and orbicular in transverse section. In regard to the disposition of these two forms of mestome-bundles, there is usually a small one between each two of the larger ones. They all are surrounded by stereome and separated from each other.

The stem.

A like structure was observed in the long internode of the stem above ground. This stem-portion is cylindric and solid; the cuticle is wrinkled and covers a small-celled epidermis, which is moderately thickened, perfectly glabrous and almost destitute of chlorophyll. The cortex consists of about fourteen strata of which the peripheral three or six are collenchymatic, and the innermost layer did not show the characteristic structure of an endodermis. A circle of thirteen mestome-bundles is imbedded in the cortex; each of these are completely surrounded by two to three layers of moderately thick-walled stereome, which enters into the leptome as a separate group in the larger bundles or merely as a bridge in the smaller ones (fig. 1). The mestome-bundles are all more or less oval in transverse section and contain a very large group of small-celled leptome, completely surrounded by a ring of scalariform and spiral vessels.

A pith of large, thin-walled cells without starch occupies the center of the stem.

By continuing our investigation to the structure of the axis of the inflorescence, we notice here the same arrangement of the tissues, but the structure is somewhat weaker. There is

only one peripheral layer of collenchyma and the stereome is reduced to a few isolated cells on the leptome-side instead of forming a closed ring around the bundle. The mestome-bundles themselves occur in a smaller number, from eight to nine, and are strictly collateral; they border on a narrow cen-

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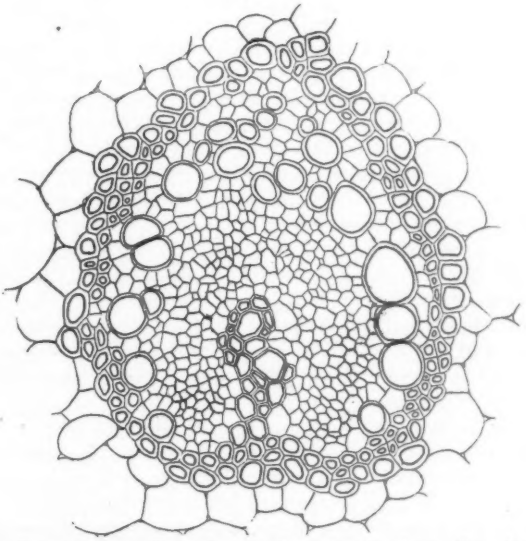


FIG. 1. Transverse section of a mestome-bundle from the stem above ground; 500 × natural size.

tral cylinder of pith. A corresponding structure is to be observed in the peduncle of the flower, but this possesses only two mestome-bundles, both of which are collateral.

The leaf.

The petiole: About three almost continuous, subepidermal layers of collenchyma surround the thin-walled cortex in which only a small amount of chlorophyll was observed. There is no stereome and no endodermis is differentiated. Seven collateral mestome-bundles traverse the petiole; they are arranged in a crescent corresponding with the outline of the petiole, and the mediane is the largest.

The blade: A thin smooth cuticle covers an epidermis with the outer cell-walls slightly thickened on both faces of the leaf-blade; the stomata are level with the epidermis and they are not parallel with the longitudinal axis of the blade; they occur only on the lower face. The chlorenchyma consists of five homogenous layers of oblong cells, which are not perpendicular, however, on the leaf-surface; this tissue is a little more

open on the lower face, thus representing some kind of pneumatic tissue. No stereome is developed, but there is a prominent ridge of colorless tissue above and below the midrib and the larger secondaries which becomes collenchymatic where it borders on the epidermis. But this is the only mechanical tissue in the leaf. The mestome-bundles are all collateral and single.

Characteristic of *Croomia pauciflora* is, thus, the structure of the mestome-bundles in the stem above ground, being leptocentric as well as in the rhizome, but simply collateral in the axis of the inflorescence, in the peduncles and in the leaves. The presence of similar leptocentric mestome-bundles is, moreover, characteristic of the genus *Roxburghia* in accordance with Mr. Lachner-Sandoval's investigations, cited above. This peculiar structure, where the leptome is surrounded, more or less completely, by the hadrome, is well known from various other orders among the Monocotyledones, but mostly from the rhizomes of these*; it is known, also, from mestome-bundles of certain Dicotyledones, which are located in the pith. In other words, it seems as if this peculiar structure of the mestome-bundles is principally observable in storage-organs and tissues: rhizomes and pith. But in the *Roxburghiaceæ* this structure is, furthermore, met with in the stem above ground instead of only in the rhizome.

Another peculiarity is the presence of stereome in the leptome, sometimes as an isolated group in the larger mestome-bundles or as a bridge in the smaller ones. The occurrence of thick-walled cells in the leptome has been described by several authors and defined as an abnormal thickening of the companion cells or, in some instances, of the sieve-tubes themselves instead of pertaining to the adjoining strata of stereomatic tissue. However it has been admitted that it is only occasionally that such thick-walled cells in the leptome are clearly distinguishable from true stereome-cells. In *Croomia*, as far as the writer has been able to ascertain, these cells were inseparable from the supporting layers of stereome; thus we have described them as belonging to this tissue.

It appears as if leptocentric mestome-bundles in stems above ground are uncommon, at least among the Monocotyledones. No such case has, so far, been recorded in the voluminous literature dealing with *Gramineæ* and *Cyperaceæ*, and Mr. Schulze does not mention the occurrence of such structure in any of the *Liliaceæ*, *Hæmodoraceæ*, *Hypoxideæ* or *Velloziaceæ*, which he has studied and described in his interesting paper on these orders.†

Brookland, D. C., April, 1905.

*Compare Chrysler, M. A.: The development of the central cylinder of *Araceæ* and *Liliaceæ* (Bot. Gazette, vol. xxxviii, p. 161, 1904).

†Engler's bot. Jahrb., vol. xvii, p. 295, 1893.

ART. VII. — *The Relative Proportion of Radium and Uranium in Radio-active Minerals;* by E. RUTHERFORD and B. B. BOLTWOOD.

THE experiments made by one of us* have shown that within the limit of experimental error the amount of radium present in radio-active minerals is proportional to the content of uranium. The amount of radium corresponding to each gram of uranium in a mineral is thus a definite constant which is of considerable practical as well as theoretical importance.

The proportionality between the content of uranium and radium in radio-active minerals strongly supports the view that radium is a decomposition product of uranium. According to the disintegration theory, the amount of radium per gram of uranium present in a mineral should be a constant whose value can be approximately deduced if the relative activity of pure radium and pure uranium is known.

In order to determine the amount of radium associated with one gram of uranium it is only necessary to compare the activity of the emanation produced by a standard quantity of pure radium bromide with that produced by a quantity of mineral containing a known weight of uranium.

In the experiments which are to be described, a standard solution of radium bromide was prepared from a specimen of radium bromide, which had been found experimentally by Rutherford and Barnes to give out heat at a slightly greater rate than 100 gram-calories per hour. The radium bromide was, therefore, probably pure. About one milligram of the salt was taken and weighed as accurately as possible on a balance. The weighing was confirmed by comparing the relative gamma-ray effect produced on an electroscope by the sample in question and the effect produced by a quantity of radium bromide weighing 23·7 milligrams. The determinates by the two methods were found in good agreement.

The known weight of radium bromide was dissolved in water and solutions were successively made up which contained 10^{-2} and 10^{-4} milligram of radium bromide per cubic centimeter. Of the more dilute solution a quantity equivalent to 1·584^{cc} was carefully weighed out, transferred to a glass bulb having a capacity of about 100^{cc} and diluted to a volume of about 50^{cc} with pure, distilled water. The bulb was sealed and allowed to stand for about 60 days in order that the maximum quantity of emanation might accumulate. At the end of this period the emanation was completely removed by boiling the

* Boltwood, Phil. Mag. (6), ix, 599, 1905.

solution and was transferred to an air-tight electroscope, in which its activity was measured. The observed activity corresponded to the emanation from $1{\cdot}584\times10^{-4}$ milligram of radium bromide, which was assumed to be equivalent to $0{\cdot}926\times10^{-4}$ milligram of radium.

The activity of the maximum or equilibrium quantity of emanation produced by the radium associated with one gram of uranium in a radio-active mineral was determined by the method which has already been described.* The mineral chosen was a very pure sample of uraninite from Spruce Pine, N. C., containing 74·65 per cent of uranium.

The activity of the emanation from the standard radium bromide solution was equal to 24·24 divisions per minute. The activity of the emanation from 0·1 gram of the mineral was equal to 14·45 divisions per minute, corresponding to 193·6 divisions per minute for each gram of uranium present. These values indicate that *the quantity of radium associated with one gram of uranium in a radio-active mineral is equal to approximately* $7{\cdot}4\times10^{-7}$ *gram.* One part of radium is therefore in radio-active equilibrium with approximately 1,350,000 parts of uranium.

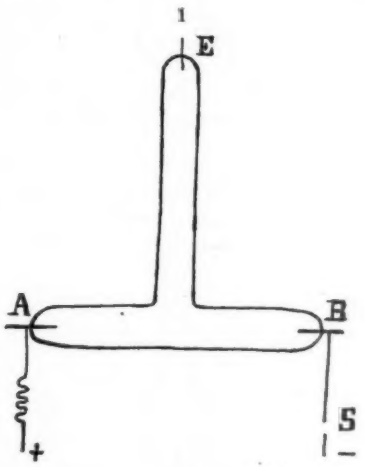
By the application of these numbers to the ordinary ores of uranium it is possible to determine their actual content of radium. Thus a high-grade pitchblende ore containing 60 per cent of uranium carries approximately 0·40 gram of radium, equivalent to 0·69 gram of radium bromide, per ton of 2,000 pounds. A low-grade 10 per cent uranium ore will contain per ton approximately 0·067 gram of radium, equivalent to 115 milligrams of radium bromide.

The amount of radium occurring with uranium is about the amount to be expected if uranium is the parent of radium, but a satisfactory comparison of theory with experiment is not possible until the relative activity of pure radium and pure uranium is more accurately determined. Experiments in this direction are in progress and the results will be given in a later paper. A method has been devised for determining in a radio-active mineral the proportion of the total activity due to the presence of uranium, radium and the other radio-active bodies. The results obtained lead to the conclusion that actinium is not a direct product of uranium in the same sense as is radium. An account of these experiments will be published later.

* Boltwood, loc. cit.

Art. VIII.—*Side Discharge of Electricity;* by John Trowbridge.

The installation of a large storage battery of 10,000 to 20,000 cells presents many interesting problems in regard to insulation; and modern theories of ionization receive great support from a study of the phenomena observed in the region surrounding the poles of the battery. There is a great probability of an invisible ionization which is constantly taking place between the earth and the battery.

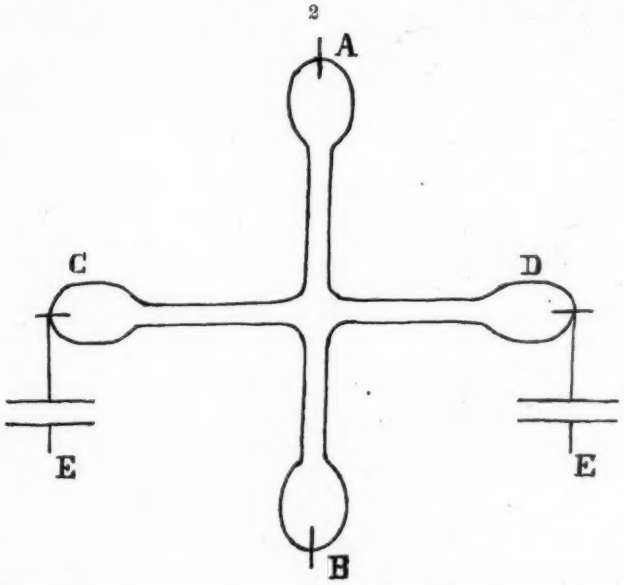


Such ionization immediately becomes visible in an interesting form of Geissler tube shown in fig. 1.

The terminal A is connected permanently with the pole of the battery through a large water resistance (several megohms). The terminal B is connected to the negative pole by a spark gap S. E is connected to the earth. At the instant the spark occurs a brilliant side discharge occurs between E and B. If the negative pole of the battery is permanently connected through the large water resistance to B, and A connected by a spark gap to the positive pole of the battery, the side discharge takes place between E and A. At the same time that these side discharges take place, a discharge passes between A and B. It is evident that the capacity of the region outside the battery, the room, and building charges up under the difference of potential between it and the poles of the battery, a difference

of potential which is greater than that between A and B, which are connected by the small resistance of the rarified gas.

This phenomenon suggests a photometric method of comparing the capacity of large condensers and also of obtaining the capacity of the immediately surrounding space. Fig. 2 represents a modification of the tube represented in fig. 1. To the arm C and D of the cross are attached the condensers which are to be compared. At the instant of the completion



of the circuit with the storage battery under the conditions mentioned above, two side discharges take place from C and D either to A or B. By bringing the light of these two simultaneous discharges into a suitable photometric arrangement, one can compare the capacity of the condensers to the degree of accuracy obtainable by ordinary photometric determinations. Since it is difficult to obtain an estimate of the capacity of large bodies of irregular shape and of large extent, this method may be of use. By a suitable vacuum tube and proper exhaustion the method does not require a large number of cells.

It was noticeable that when a stratified discharge was established between A and B fig. 1, there being no spark gap in the circuit except that of the rarified space between A and B,

fluctuating feeble discharges took place to earth through E. This phenomenon seems to indicate a discontinuity in the stratified discharge.

When the small spark gap, either at the positive or negative pole, is of a suitable length, the discharges between E and either pole of the battery succeed each other so rapidly that the side discharges to earth appear continuous. If a large condenser is substituted for the earth at E, one plate of the condenser being connected to earth, the time between each discharge is lengthened. This time of charging can be well illustrated by connecting condensers directly through a large water resistance directly to the poles of a large storage battery and allowing the condensers to discharge through a spark gap. The time of discharge can be regulated through a wide range and the arrangement can be termed an electric clock.

It is probable that in the case of lightning side discharges take place to the earth in the manner indicated by this method; the potential between the positively and negatively charged clouds rising to a higher value than that between the clouds; the earth space beneath the clouds acting as a localized capacity.

ART. IX.—*The Effect of High Temperatures on the Rate of Decay of the Active Deposit from Radium;* by HOWARD L. BRONSON.

IN the course of a careful investigation of the decay of the active deposit from radium, some experiments of Curie and Danne* were repeated. These consisted in determining the change which high temperatures produce on the rate of decay of this active deposit. As a result of the following experiments, a different conclusion from that offered by Curie and Danne has been arrived at.

Miss Gates† showed that high temperatures produced at least a partial separation of the components of the active deposit from radium, owing to the fact that they are not all equally volatile. Curie and Danne verified this, and also found that the rate of decay of the active deposit apparently was permanently altered by exposure to temperatures between 650° and 1300° C. The following table gives some of their results:

t	θ
6 30°	29·3
8 30	24·6
10 00	21·0
11 00	20·3
12 50	24·1
13 00	25·4

Here t is the temperature in degrees centigrade to which the active deposit was raised, and θ is the "period," that is the time in minutes required for the activity to fall to half value. From this table it is seen that the rate of decay increased as the temperature was raised from 650° to 1100°, but decreased again at still higher temperatures. Curie and Danne also stated that the decay curves were exponential, and they therefore concluded that the rate of decay had been permanently altered.

In the following experiments the measurements were all made with an electrometer, and the "constant deflection method" described by the writer‡ was employed. The active deposit was collected on platinum wires by connecting them to the negative pole of a battery of 400 volts, and exposing them for several hours in the emanation from radium. After removal the wires were kept for a few minutes at the desired temperature in a small electric furnace, made by Dr. C. A.

* Comptes Rendus, cxxxviii, p. 748, 1904.
† Physical Review, May, 1903.
‡ This Journal, Feb., 1905.

Timme of Berlin, and were then placed in the testing vessel. A calibration curve for the furnace had previously been made by the use of a platinum-rhodium thermo-junction.

A large number of experiments were made using several temperatures between 700° and 1100° C. An example of the kind of results obtained is given in fig. 1. A, B, C and G are four decay curves of the active deposit, which had been previously heated to about 800° C. In the case of D, E and F the temperature used was about 900° C. The time is reckoned from the removal of the wire from the

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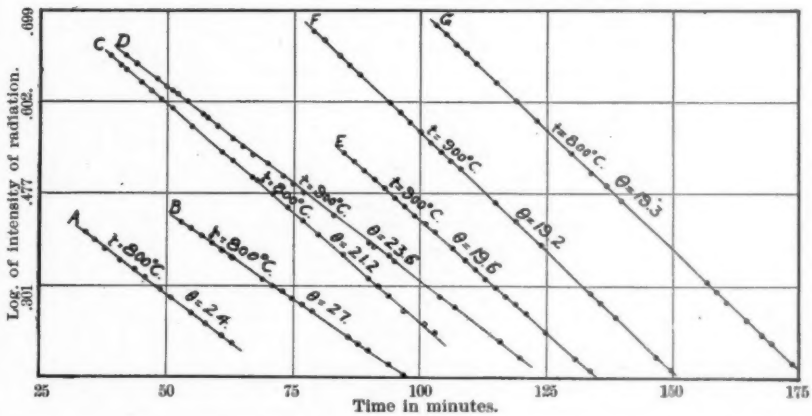
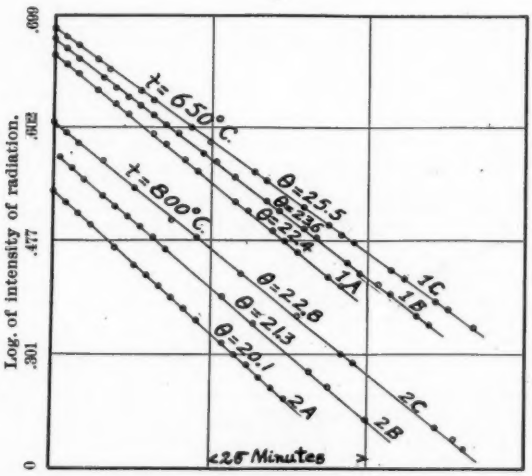


emanation. The first points on curves F and G should be at about 200 and 300 minutes respectively, as in these cases the wires were not placed in the furnace until several hours after their removal from the emanation. These curves are apparently exponential, as was found by Curie and Danne, but θ does not at all seem to be a function of the temperature, for its value seems just as liable to change when the temperature is kept the same as when a different temperature is used. In fact θ was found liable to take on any value between nineteen and twenty-seven minutes, and this was true for all temperatures between 700° and 1100°. Among these values of θ there were, however, a large number between nineteen and twenty-one minutes. This was nearly always the case when the wire was not heated until several hours after removal from the emanation.

Now Rutherford* has shown that, neglecting the first half

* Philosophical Transactions, 204, p. 196.

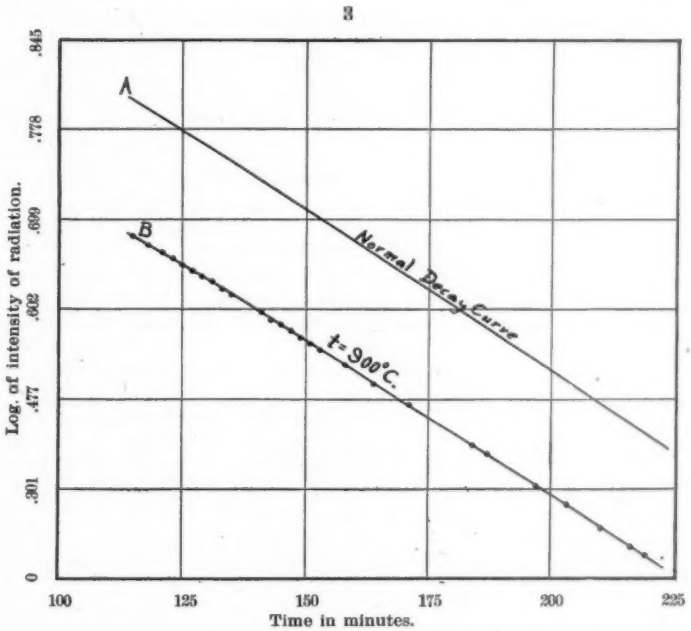
hour, the decay curve of the active deposit from radium is satisfactorily explained by assuming two successive products, radium B and radium C; the matter B giving rise to no rays, and the matter C to α, β and γ rays. Taking twenty-eight minutes as the decay period of one of these, he calculated that the period of the other must be twenty-one minutes. Theoretically it makes no difference whether the longer period belongs to the matter B or C, but the above mentioned experiments of Curie and Danne supplied the evidence which decided this question in favor of the matter C.



The fact that so many of the values of θ, obtained after heating the deposit, were in the neighborhood of twenty-one minutes, made it seem quite possible that the matter C had the shorter period, and not that its period had been changed by heating. Also the fact that the rayless change in the active deposits from thorium and actinium each have a longer period of decay than the change immediately following, possibly is evidence in the same direction. If this be the case, then all the larger values of θ must have been produced by mixtures of the two kinds of matter, B and C, in different proportions. This, however, would not give an exponential decay curve, but the period would continue to increase, since the ratio of the matter having the longer period to that having the shorter would increase with the time.

In order to see if this were the case, the decay of the activity of the heated deposit was measured over a long period of

time. Fig. 2 shows the result of two experiments of this kind. 1 A, 1 B and 1 C are three sections of the same curve, obtained after heating the active deposit to about 650° C. 1 A was taken immediately after heating, 1 B after about two hours, and 1 C after about four hours. The respective values of θ were 22·4, 23·6, and 25·5. In the case of curve 2, the temperature used was about 800°C. 2 A was taken immediately after heating, 2 B after about one hour, and 2 C after about



two and one-half hours, and the values obtained for θ were, respectively, 20·1, 21·3, and 22.8.

The above results furnished very strong evidence in favor of the supposition that the heating did not actually alter the rate of decay of the active deposit. In order to make this conclusive, the wire on which the active matter had been deposited was sealed, before heating, in a piece of glass combustion tubing. This prevented the escape of any volatile products, which in the previous experiments had evidently been the uncertain factor. By exhausting the glass before sealing, it was found that it would stand temperatures high enough to melt the copper wires, which were used in this case.

A number of experiments were made in this way, using the same temperatures as before, but in no case did θ fall below twenty-six minutes.

B, fig. 3, is the logarithmic decay curve, obtained when the active deposit was sealed in a glass tube and heated to 900° C. A is the normal decay curve for the active deposit. These curves are approximately parallel, showing that the rate of decay had not been measurably changed by a temperature of 900° C.

It is thus evident that temperatures between 700° and 1100° C. have very little, if any, effect on the rate of decay of the active deposit from radium. The results obtained by Curie and Danne and those given in the present paper are satisfactorily explained by assuming that radium C has the shorter instead of the longer of the two periods, and that radium B is the more volatile, but that in general a part of it still remains on the wire after heating.

The measurements made in this investigation also seem to show that both twenty-eight and twenty-one minutes are too large for the decay periods of radium B and C, and that twenty-six and nineteen minutes are nearer right. Experiments are at present in progress which it is hoped will settle this definitely.

In conclusion, I desire to thank Professor Rutherford for his many suggestions and kind supervision of this work.

Macdonald Physics Building,
McGill University, Montreal, June 5, 1905.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Amounts of Neon and Helium in the Air.*—Sir William Ramsay, in connection with previous investigations, has roughly estimated the amount of helium in the atmosphere at one or two parts per million, and the amount of neon at one or two parts per hundred thousand. He has now made more accurate determinations of these constituents, and finds one volume of neon in about 81,000 volumes of air, or ·00086 per cent by weight, and one volume of helium in about 245,000 volumes of air, or ·000056 per cent by weight. (In the published article the percentages are erroneously given as 100 times smaller than the above.) The method used in these determinations was based upon the absorption of gases by charcoal as recently studied by Sir James Dewar. The charcoal was kept at $-100°$, at which temperature neither neon nor helium is absorbed in appreciable quantities, while the other constituents may be almost completely absorbed by repeating the treatment. In this way about 2^{cc} of gas were left from the treatment of 18 l. of air, and after the residual air had been removed by sparking, the residue, which gave no spectrum of argon, was measured in a delicate apparatus. The neon was then condensed by charcoal at the temperature of liquid air in order to separate it from helium as far as possible, and the separate gases were afterwards measured. It appeared that this separation was a satisfactory one, although not absolute, and that the helium determination may be somewhat too high.

It is interesting to notice that Ramsay collected the lighter gases from 540^{cc} of liquid air, corresponding to about 400 l. of the gas, and that while he obtained a fair yield of neon and helium, he could find no evidence of the presence of hydrogen in this residue. The result appeared to show that there must be less hydrogen in the air than 1/500 of the combined neon and helium, but the author does not regard the experiment as quite conclusive.—*Chem. News*, xci, 203. H. L. W.

2. *The Radio-activity of Thorium.* — An account is given by O. Sackur of a product obtained by fractionating a mixture of barium and radium bromide obtained from 2·5 tons of thorianite. It was found by Hahn that the more soluble fractions of this mixture of bromides did not continually decrease in activity, as would be expected from the removal of radium, but, after a series of crystallizations, became more active. A strongly radio-active product was obtained from this liquid by precipitation with ammonia, and by solution in acid and precipitation with ammonium oxalate the activity was still further concentrated. It was found that the emanation from this substance lost one-half of its activity in 52–55 seconds, and that it consequently corresponds to the thorium emanation. This was confirmed by determining

the decay of its induced activity, which showed a period of 11·2 hours for the half value, while Rutherford has given about 11 hours as the characteristic period for the induced activity produced by the thorium emanation. It may be considered certain, therefore, that the substance obtained by Hahn gives off the thorium emanation; but, since comparative tests showed that the product possesses a power of emanation about 250,000 times greater than thorium, it is concluded that it contains a new radioactive element which produces the thorium emanation. The question arises whether two distinct elements may produce the same emanation, or whether the activity of thorium may be due to a mixture with this new element—a question which has not yet been decided.—*Berichte*, xxxviii, 1756. H. L. W.

3. *The Use of Quartz Apparatus for Laboratory Purposes.*—Mylius and Meusser of the Phys.-Techn. Reichsanstalt at Charlottenburg have investigated the action of various liquids upon quartz vessels by finding the loss in weight after such action. They find that water has no appreciable effect either at ordinary temperature or at 100°. In fact, the electrical conductivity of water may be diminished by boiling off the carbonic acid in these vessels. The vessels are attacked by alkaline liquids, and in this respect they appear to possess no advantage over glass. Dilute acids, with the exception of hydrofluoric, and concentrated sulphuric acid have no appreciable action at 100°, or at lower temperatures. Corrosion is produced by phosphoric acid when it is concentrated above 400°, and white silicylphosphate separates. Quartz vessels possess the property of absorbing certain dyes from their solutions. The amounts thus absorbed are exceedingly small, forming a uniformly colored film when the vessels are rinsed, and this can be removed by the use of hot solvents.—*Zeitschr. Anorgan. Chem.*, xliv, 221. H. L. W.

4. *Permeability of Quartz Vessels to Gases.* — It has been observed that vessels of quartz glass are permeable to helium at temperatures below red heat, and Berthelot has recently found that other gases, for instance, atmospheric nitrogen, are capable of penetrating tubes of this material at a temperature of about 1,300°. This property of fused quartz will somewhat limit its applications for investigations at high temperatures.—*Comptes Rendus*, cxl, 821. H. L. W.

5. *Outlines of Inorganic Chemistry;* by Frank Austin Gooch and Claude Frederic Walker. 12mo, pp. xxiv+233 +514. New York, 1905 (The Macmillan Company).—This textbook of elementary chemistry, a large and comprehensive work, is divided into two distinct parts, "inductive" and "descriptive." About twice as many pages are devoted to the latter part as to the former. It has been the aim of the authors to introduce the student to chemistry by consideration of the simplest and fewest things, and much attention has been paid to the inferences to be drawn from experimental phenomena. Part I takes up the consecutive experimental development of the principles upon which

chemistry rests. Only in the final chapter of this part is the notion of the atom introduced. Part II is arranged in accordance with a modification of Mendeléeff's Periodic System. Graphic symbols are freely used, and ionic terminology has been employed, although the extreme developments of the idea of free ions have not been made use of. Careful introductions to group characteristics, and full summaries covering the relations in detail, are given in this part of the book. H. L. W.

6. *Spectroscopic Analysis of Gas Mixtures.* — Many investigators have endeavored to use the sensitive portion of the positive discharge in a Geissler tube as a qualitative means of determining proportions of gases in mixtures. Secchi, however, found that oxygen of air could not be detected in this way. E. Wiedemann has shown that mercury vapor masks the hydrogen and nitrogen spectra even when a large proportion of these gases are present. Collie and Ramsay found the method inoperative in the case of some gases. J. E. LILIENFELD, by suitable forms of tubes and proper arrangement of electrical circuit, finds that the method can be made extraordinarily sensitive, and gives the following table:

Smallest visible quantities.	Collie and Ramsay.	E. Wiedemann.	Lilienfeld.
He in N	10%	--	0·7 %
Ar in N	37%	--	0.932 % (in air)
N in Hg	--	approx. 30 %	0·7 %
H in Hg	--	" 30 %	0 7%

The author shows that the theory of ionization explains the masking of the spectra of gases in a mixture. The presence of one gas prevents the dissociation of another gas.—*Ann. der Phys.*, No. 5, 1905, pp. 931–942. J. T.

7. *The FitzGerald-Lorentz Effect.*—FitzGerald and Lorentz, in reference to Michelson and Morley's experiments on the drift of the ether, suggested that the dimensions of the apparatus might be modified by its motion through the ether. Professors MORLEY and MILLER have, therefore, taken up the experiment anew and conclude their paper as follows: "We may declare, therefore, that the experiment shows that if there is any effect of the nature expected, it is less than the hundredth part of the computed value. If pine is affected at all, as has been suggested, it is affected to the same amount as sandstone, If the ether near the apparatus did not move with it, the difference in velocity was less than 3·5 kilometers per second, unless the effect on the materials annulled the effect sought. Some have thought that the former experiment only proved that the ether in a certain basement room was carried along with it. We desire to place the apparatus on a hill covered only with a transparent covering, to see if an effect could be there detected." The authors propose to make this experiment.—*Phil. Mag.*, May, 1905, pp. 680–685. J. T.

8. *The Normal Element.* — The weighty questions in regard to the conditions of stability of the mercuric sulphate do not appear to be solved. At present the silver voltameter is as reliable as the Weston element, and there does not appear any reason why those countries which have adopted the silver voltameter as a standard should give it up for the Weston element.—*Physk. Techn., Reichsanstalt*, 1904. J. T.

9. *Influence of Character of Excitation upon Structure of Spectral lines.*—If a Geissler tube is excited by electric oscillations, the fine spectral lines undergo a marked change, which is probably due to an increase of temperature arising from the electrical oscillations.—*Phys. Techn. Reichsanstalt*, 1904. J. T.

10. *On the Radio-active Minerals.*—In a paper upon this subject in the Proceedings of the Royal Society (A, lxxvi, 88–100) the author, R. J. STRUTT, summarizes his results as follows:

(1) The conclusion, that the amount of radium in a mineral is proportional to the uranium, is confirmed. The investigation of this point has brought to light the existence of uranium in some minerals not previously known to contain it, monazite, for instance.

(2) It is shown that thorium minerals invariably contain the uranium-radium combination. The observation is difficult to interpret, but it may possibly indicate that thorium is producing uranium.

(3) Helium never occurs except in very minute quantity unless thorium is present. The helium of minerals, therefore, is probably produced more by thorium than by radium.

(4) Thorium minerals vary much in emanating power. Some retain nearly all their emanation, others give off large quantities.

11. *On the Absence of excited Radio-activity due to temporary Exposure to γ-rays.*—This subject is discussed by J. J. Thomson and by H. A. Bumstead in brief articles published in the Proceedings of the Cambridge Philosophical Society, vol. xiii, part 2 (pp. 124, 125–128). Thomson says:

"Experiments were made to see if the radiation given out by metals could be temporarily increased by exposure to the radiation from radium. The method used was to measure the saturation current inside a closed metallic vessel, then to place a sealed glass tube containing 30 mg. of radium bromide inside the vessel and leave it there for times varying from one hour to ten days; the radium was then removed and as soon as possible afterwards the saturation leak again measured; experiments were made with vessels made of lead, brass, tin, but no increase in the saturation current attributable to exposure to the radium was ever detected. The measurement of the saturation current took at least five minutes after the removal of the radium, so that a very short-lived increase might escape detection by this method."

The last mentioned point was independently investigated by Bumstead, who experimented with copper, lead, tin and uranium nitrate by a method specially devised for the purpose, but also without positive results. The author remarks:

"With the four substances tested, therefore, the result is negative. If they retain the power of giving out any rays capable of penetrating $0{\cdot}7^{cm}$ of air and $0{\cdot}00005^{cm}$ of aluminium, for 0·009 seconds after exposure to the β- and γ-rays from 30 milligrams of radium, these rays must be considerably less intense than those due to a layer of uranium salt whose surface-density is 1 milligram per square centimeter."

12. *Handbuch der Spectroscopie;* von H. KAYSER. Dritter Band. Pp. viii, 604; 3 plates, 94 figures. Leipzig, 1905 (S. HIRZEL).—Upon the appearance of the first volume of this work on Spectroscopy by Professor Kayser, a somewhat extended notice was published in this Journal, giving an outline of the whole plan (see vol. x, 464, 1900). Since then the second volume has appeared, followed now by the third. So thorough and exhaustive, however, is the work which the author is doing, that it has been found necessary to enlarge the original plan and devote two volumes instead of one to the subject of absorption, here discussed. The present volume contains the description of methods and of apparatus for the investigation of absorption spectra, a discussion of our present knowledge in regard to the connection between absorption and the constitution of the substance; and, finally, a presentation of the results of observations both for inorganic and artificial organic substances. The remainder of the subject, reserved for the next volume, includes the discussion of the natural organic coloring materials, both vegetable and animal, and also the phenomena connected with absorption; that is, dispersion, fluorescence and phosphorescence. The devotion with which the author has given himself to the subject and the thoroughness of his treatment of the entire subject matter are both noteworthy. In the preparation of the first volume he has had the assistance of Professor W. N. Hartley, of Dublin, who discusses very fully the question of the connection between constitution and absorption, where the author regarded himself as not sufficiently informed in reference to the chemical side to enable him to handle it satisfactorily. It needs hardly to be said that this chapter (pp. 144–316) shows the same degree of completeness and careful handling which characterizes the whole work.

II. GEOLOGY AND NATURAL HISTORY.

1. *United States Geological Survey, Charles D. Walcott, Director.*—Recent publications by the U. S. Geological Survey include the following:

FOLIOS: No. 120, Silverton Folio, Colorado. This includes a description of the Silverton Quadrangle by WHITMAN CROSS, ERNEST HOWE and F. L. RANSOME; also geography and general geology of the Quadrangle by WHITMAN CROSS and ERNEST HOWE.

No. 121, Waynesburg Folio, Pennsylvania, by RALPH W. STONE.

BULLETINS. No. 243. Cement Materials and Industry; by EDWIN C. ECKEL. 395 pp., 15 plates.

No. 255. The Fluorspar Deposits of Southern Illinois; by H. FOSTER BAIN. 75 pp., 6 plates.—This bulletin gives an account of the fluorspar mines in Hope and Hardin counties in the extreme southern part of Illinois. The principal mines are near Rosiclare, Elizabethtown and Cave-in-Rock on the Ohio river in Hardin County. The discovery of the deposits goes back to 1839, although the material was not definitely mined until the early 70's. The author discusses the geology of the region in detail, and shows that the deposits of fluorspar, with the accompanying ores of lead and zinc, are vein deposits occurring along faulting fissures. The amount of fluorspar produced from the region in 1903 was 18,360 short tons, as compared with 29,000 tons from Kentucky and 628 from Arizona and Tennessee. The highest grade is used in the enameling, chemical and glass trades. The second grade is used in steel making, being used in open-hearth work because of the great fluidity which it gives the slag. Twenty thousand tons are used annually in this work. The lowest grade is used in foundry work, and there seems to be an almost unlimited market for it.

WATER SUPPLY PAPERS. No. 126. Report of Progress of Stream Measurements for the calendar year 1904. Prepared under the direction of F. H. NEWELL, by N. C. GROVER and JOHN C. HOYT. Part III, Susquehanna, Patapsco, Potomac, James, Roanoke, Cape Fear and Yadkin river Drainages.

No. 260, Contributions to Economic Geology, 1904; S. F. EMMONS, C. W. HAYES, geologists in charge. 620 pp., 4 plates, 25 figures.—The prompt and liberal return which the Geological Survey makes to the country at large for its pecuniary support is well shown by the numerous publications, appearing each year, which to a greater or less extent are devoted to Economic Geology. The publications of 1904 of this character, for example, included a Monograph by Van Hise; ten professional papers, chiefly on ore deposits in different regions; three bulletins and two folios, the last on the Globe and Bisbee Districts in Arizona. The present bulletin is the third bearing this title, its predecessors being Nos. 213 and 225, for the years 1902 and 1903. The object of these particular bulletins is to bring before the public, with all possible promptness, the economic results obtained by the Survey parties. Many of the subjects here presented are to be more fully discussed in other papers, appearing independently. The production of gold and silver are naturally presented at length; also that of tin, copper, zinc, lead and iron. Special chapters are given to some of the rare elements, as molybdenum, vanadium and uranium in Utah, etc. Coal, oil, gas and salt also form the subjects of special chapters. Many different authors contribute to the volume.

2. *Preliminary Report on the Geology and Underground Water Resources of the Central Great Plains;* by N. H. DAR-

TON. 433 pp., 4to, 72 plates, 18 figures. U. S. Geological Survey, Professional paper 32.—The area covered by the discussion in this volume embraces nearly all of South Dakota, Nebraska and Kansas, and extends westward to central Wyoming and Colorado. Over most of the region the rolling plains of the eastern portion rise gradually and uniformly to the westward. The geological structure is comparatively simple for the most part, with the exception of the Black Hills region in South Dakota and portions included of the Big Horn and Laramie Ranges in Wyoming and Colorado. The geological features are very fully presented in the first half of the present volume, the descriptions being based upon work by numerous geologists in the past, supplemented by that of Mr. Darton and his assistants. Numerous excellent views from photographs, and also geological maps and sections, accompany the text. The chief interest of the investigation, however, lies in the question of water supply, which in many parts of the region is very deficient and must be supplemented where possible by artesian wells. Great numbers of these have already been sunk, many of them with excellent results, and the study that Mr. Darton has made so carefully of the region gives promise that still more will be accomplished in the future. Although the rocks of Cambrian, Ordovician, Carboniferous and Jurassic age are believed to underlie the entire area, almost no wells exist lower than the Cretaceous, and the water horizon of the Dakota sandstone is the most widely extended and the most useful. The author states that over a thousand deep wells have been sunk east of Missouri River most of which are from 500 to 1000 feet in depth and yielding a large supply of flowing water, most of which is used for irrigation. The aggregate flow from these wells is estimated to be about 7,000,000 gallons a day. From the Fox Hills–Laramie formation the supply is much more limited. The Tertiary deposits also yield useful wells, particularly in the Denver basin. Finally, the alluvial deposits of the Quaternary afford large quantities of water from limited depths (5 to 50 feet), while the tubular wells in east South Dakota and east Nebraska bring the water of the glacial drift mainly at the base of the till.

The great pressure under which the water exists is a point of much interest and shows that it must owe its origin to an altitude some thousands of feet above. Several wells in eastern South Dakota, for example, show surface pressures over 175 pounds to the square inch, and two are a little over 200 pounds; the latter indicating a pressure of 780 pounds at the bottom of the well. The theoretical hydrostatic pressure is, however, much diminished by the leakage of water to the east and south. Full details are given in the volume in regard to existing wells, and the work closes with a chapter upon the Economic Geology of the region, that is, the supplies of coal, oil, gas, salt, etc.

3. *Origin of the Channels surrounding Manhattan Island, New York;* by W. H. HOBBS. Bull. Geol. Soc. America, xvi,

pp. 151–182, plate 35.—The author has made a careful study of the data now obtainable in regard to the various channels around the Manhattan Island, with a view to deciding as to their probable origin. In 1881 the subject was discussed by J. D. Dana* and their formation ascribed to the presence of belts of limestone whose erosion was believed to explain the topographic features. Hobbs, however, concludes that there is no sufficient evidence of a correspondence between the directions of belts of limestone, or dolomite, and those of the various channels; on the contrary, he regards them as owing their origin to lines of jointing and displacement. The account of Julien is appealed to, giving the location and orientation of the principal dikes on the island, which quite generally run along the direction of the avenues. Julien shows that the orientation of the drainage has been largely determined by the planes of fracture. Julien has also shown that, besides these, there is a system of cross faults nearly at right angles to the avenues, or, in other words, along the cross streets. Thus the fissure planes occupied by the dikes, and the perpendicular series often occupied by quartz lenses and pegmatite, both correspond very closely in their direction with the two series making up the main drainage system. The observations of the author also show that many of the most prominent joint-planes in the rocks of the island have the direction of the cross fissures, N60°W. He concludes that "the rôle of the dolomite in fixing the locations of the present channels would thus appear to have been a subordinate one, excepting in so far as the direction of its boundaries has been determined by its fissure planes."

4. *The Isomorphism and Thermal Properties of the Feldspars.* Part I, Thermal Study ; by ARTHUR L. DAY and E. T. ALLEN, pp. 13–75. Part II, Optical Study; by J. P. IDDINGS, pp. 77–95. Plates I to XXVI. With an introduction by GEORGE F. BECKER, pp. 4–12. Publication No. 31 of the Carnegie Institution of Washington.—The first part of this volume gives the complete presentation of the results obtained by Day and Allen in their very important work upon the thermal relations of the feldspars. This is accompanied by a series of twenty-six beautiful plates illustrating the crystallization of the various compounds and the effect of very high temperatures upon them. An extended abstract of this paper has already been given in the number of this Journal for February, 1905 (pp. 93–142).

Part II gives the results of an optical study by Iddings of the series of lime-soda feldspars synthetically obtained by crystallization in open crucibles from fused constituents. In addition to the detailed description of thin sections of the individual compounds, a general summary is given which contains some points of so much importance in petrography that we quote largely from it:

"The results of these synthetical experiments agree closely in some respects while differing in others. They agree in general

* This Journal, xxi, 25, 443; xxii, 313, 1881.

in the habit and arrangement of the crystals of the different feldspars produced, while differing in the size of the crystals of the various feldspars according to their composition. These results have an important bearing on the problem of texture and granularity in igneous rocks.

First, as to the habit of the feldspar crystals produced from solution of the feldspar constituents without admixture of other material. So far as can be determined by microscopical study of the sections, the crystals are in most cases blade-like in form; that is, they are elongated plates. They vary, however, from one extreme to another, being in some cases equidimensional plates of extreme thinness, in other cases prisms, elongated in one direction with the other two dimensions equal. The development of these forms takes place in feldspars of various compositions, and appears to be chiefly a function of the rate of crystallization and not of the chemical composition of the feldspar, except as this modifies the viscosity of the solution. It is not possible to recognize any fixed relation between the habit of the crystals and the composition of the feldspar. This is, of course, in accord with the well-known isomorphism of the feldspar group.

The common mode of crystallization in these preparations is that of spherulitic aggregations, more or less completely developed in spherical forms.

The elements of the spherulites are bundle- or sheaf-like aggregations of long, thin blades, which blades lie nearly parallel to one another in the middle or narrower part of the bundle, and diverge at the ends into fan-like or plumose forms. Several of these bundles or blades cross one another at the middle, and when there are a sufficient number of bundles, or when they diverge sufficiently, a completely spherulitic aggregation results.

In some cases a spherulite consists of bundles or prisms that extend uninterruptedly from the center to the outer margin, the rays of the spherulite being nearly straight. In other cases the spherulite is a composite of divergent bundles shorter than the radius, which have been added to one another as though new plumes had started from the ends of earlier ones.

In most cases the middle portion of the feldspar bundles consists of stouter crystals than the outer parts. It also appears that the middle portion is more prismatic, in certain cases somewhat cuboidal, the outer parts becoming delicately tabular. This, with the divergence in position, explains the spread of the outer part of the sphere. There is a great increase in the number of individual crystals in the outer portion of the spherulite, and in some cases the crystals also increase in size in the outer part.

The shapes of the crystals are due to the flattening of the crystal parallel to the second pinacoid (010), and its elongation parallel to the crystal axis *a*. The outlines of the plates appear to conform to traces of several pinacoids in the zone of the *b* axis, (001), ($\bar{2}$01), ($\bar{1}$01), (201), ($\bar{3}$04), ($\bar{2}$03), not all of these occurring together. It is quite probable that pinacoids in the zone of the *c* axis also may be developed, but they were not recognized.

Bladed forms in some cases prove to be aggregates of thin plates not strictly parallel to one another in the plane of flattening, so that the blade is curved and not straight in the direction of its longest axis.

In some spherulites the component crystals are prisms throughout, with no tabular flattening. The number of crystal prisms increases from the center of the spherulite outward by the development of new prisms at slightly divergent angles, in arborescent arrangement.

The most complex arrangements are produced by twinning and divergence combined, resulting in feather-like aggregates. Long, narrow, tapering blades in albite twins form a shaft, elongated parallel to the crystal axis *a*, on two sides of which diverge at a slight angle a double set of thin blades, like barbs. These consist of branched smaller blades or prisms, like barbules, the branch prisms having approximately the direction of the crystal axis *c*. The two sets in each "barb" are apparently related to one another as the halves of a manebach twin. The small prisms are composed of many subparallel plates flattened in the plane of the second pinacoid (010). These correspond to barbicels in a feather.

With respect to the size of the crystals it is extremely significant that pure anorthite (An) develops in comparatively large plates, 5^{mm} thick and 20 to 30^{mm} long, in a few hours, whereas the more sodic the feldspar the smaller the individual crystals formed under almost the same conditions of cooling. Thus with oligoclase (Ab_4An_1) the individual crystals composing a bundle of blades are considerably less than $0{\cdot}01^{mm}$ thick, probably about $0{\cdot}001^{mm}$, a difference in thickness when compared with anorthite of about 5,000 to 1. This as shown elsewhere is due to the greater viscosity of the liquid feldspars near their solidifying point as they approach the albite end of the series.

Any comparison of the grain of rocks, that is, the size of the constituent crystals, with a view to determining the physical conditions attending the solidification of the magma, must be based in the first instance on a knowledge of the behavior of the various rock-making minerals under similar physical conditions, both separately and in combination, that is, in solution with one another. The granularity of rocks is clearly a function of the chemical composition.

With respect to the homogeneity of the crystals separating from the liquid, it is observed that the great part of each crystal aggregation appears to be of one composition, but that in some cases a small proportion, probably less than 1 per cent, is different from the bulk of the feldspar, both in composition and habit. In one instance this small variant differed in composition but not in habit from the main mass of crystals.

In the first case it appears that crystallization began with feldspar richer in the anorthite molecule than the solution and developed cuboidal forms. These were prolonged into prismatic

bundles, the prisms having the composition of the main mass of crystals.

In the second case the small variant crystallized toward the end of the crystallization and contained more albite molecules than the main mass of feldspar crystals. It had the same habit as the other more calcic portion, and appears to have crystallized at the same time with it, the crystals with different optical properties being by the side of one another and not in zonal relation. Neither of the feldspars represents the end members of the series, An or Ab."

The Introduction to the volume by Becker, to whom the original plan of the work is largely due, will be read with much interest.

5. *The Tin Deposits of the Carolinas;* by J. H. PRATT and D. B. STERRETT. 64 pp. Raleigh, 1904. Bulletin No. 19 of the North Carolina Geol. Survey, J. A. Holmes, State Geologist.—The occurrence of tin in the country, and the southern states particularly, is mentioned in Bulletin No. 260 of the Geological Survey, noticed on page 70. This paper, by Pratt and Sterrett, appears from the North Carolina Geological Survey and takes up in detail the tin deposits of North and South Carolina. The first discovery of tin ore was made near Kings Mountain, North Carolina, in 1883, though but little progress was made until 1903, when the Ross mine at Gaffney, South Carolina, was discovered. During these twenty years, considerable prospecting has been done on the Carolina tin belt, so that this can now be traced quite definitely in a northeasterly direction from Gaffney, Cherokee county, South Carolina, across Gaston and Lincoln counties, North Carolina. Tin deposits also occur in Rockbridge county, Virginia.

A full account is given of the work which has been accomplished thus far, and a brief statement is added of the occurrence of tin in other parts of the country and abroad. At present, the practical work in the Carolina belt is limited to hydraulic mining in the alluvial gravels, the vein tin requiring different and more expensive treatment. Such deposits as those of the Ross mine are regarded as thoroughly remunerative, but in a large proportion of the alluvial deposits the yield of cassiterite is relatively small and this fact makes successful mining more problematical.

6. *Tubicolous Annelids of the Tribes Sabellides and Serpulides from the Pacific Ocean;* by KATHARINE J. BUSH, Ph.D. 8vo, 130 pp., 44 plates.—This admirable memoir forms part of volume xii of the reports of the Harriman Alaska Expedition. It includes a list of all known Pacific Ocean species of these groups and a very complete bibliography. The systematic portion includes full descriptions and illustrations of all the known species from California to Alaska. In the case of *Spirorbis* all the known species are reviewed from other regions also. Many of the illustrations are from photographs reproduced as heliotypes. The northwest coast of America seems to be one of the

great headquarters of the Sabellidæ, for the species are unusually large, handsome, and numerous. Many new genera and species are described and the previously known genera are revised.

A. E. V.

7. *A Student's Text-Book of Zoology*, Vol. II; by ADAM SEDGWICK. London: Swan Sonnenschen & Co. New York: Macmillan Co. 705 pp., 333 cuts.—The second volume of this excellent text-book has been received. It includes the true Vertebrata and Cephalochorda. These are treated with unusual fullness both systematically and anatomically, and are well illustrated, though a large part of the cuts are the same as those used in the well known work of Claus. About fifty cuts are new. In the case of fishes the somewhat old classification of Gunther has been followed. Many later improvements in that group might well have been adopted. On the whole, it is the best text-book on the morphology of the Vertebrata now available. A. E. V.

8. *A Preliminary Report on the Protozoa of the Fresh Waters of Connecticut;* by HERBERT WILLIAM CONN. Bulletin No. 2, Connecticut State Geological and Natural History Survey. 69 pp., 34 pls., 1905.—This report deserves more than a passing notice because it is the first attempt yet made to enumerate and illustrate all the unicellular animals found in any locality in America. As implied by the title, the present report is but the beginning of an extensive work, in which it is aimed to eventually include a general study of all the Protozoa found in the State, with a consideration of their habits, evolution, geographical distribution, and their economic relation to the purity of drinking waters. The preliminary work for such a study must be the identification of the species, and to aid microscopists in recognizing the forms already found the present report is provided with 303 figures, all of which are from original drawings by the author from specimens collected in the State, and include every species which the author has thus far recognized in the region. No attempt has been made to give names to the new genera and new or unidentified species which are thus illustrated, such forms being designated merely as "new genus" and "sp. (?)" respectively. In the final report it is intended to furnish generic and specific diagnoses of all these forms, but the present work is provided with a brief description of the recognized genera only, specific descriptions being wholly omitted. There are admirably arranged keys to orders and genera. The figures are remarkably well drawn, and are printed in such a manner as to reflect great credit on the officers of the Survey, as well as on the author. The excellence of these plates is in striking contrast with the character of the illustrations published in the majority of State reports in recent years.

The value of this work will go far in justifying the inauguration of the newly established Geological and Natural History Survey of the State and forms a worthy leader of its series of zoological publications. W. R. C.

9. *Études sur l'Instinct et les Moeurs des Insects;* by J.-H. FABRE. Souvenirs Entomologiques, 9e Série, pp. 374. Paris.—This ninth volume of the author's very interesting accounts of the domestic life of insects describes in popular language some of his extensive observations on the habits and instincts of several species of spiders, a scorpion, gall insects, etc. W. R. C.

10. *The Rocky Mountain Goat;* by MADISON GRANT. Reprinted from the 9th Annual Report of the New York Zoological Society. New York, Office of the Society, 1905. 36 pp.—A well illustrated account of the systematic position, habits, and distribution of this little-known game animal, which is not strictly a goat, but the sole American representative of the *Rupicaprinae*, or mountain antelopes. W. R. C.

11. *A Catalogue of North American Diptera (or two-winged Flies)*; by J. M. ALDRICH. 680 pp. Washington, 1905. Smithsonian Miscellaneous Collections, No. 1444, part of volume xlvi. —The author states that this work is based upon the second edition of Osten Sacken's Catalogue of North America Diptera, published in 1878. It is by no means a reproduction of this, however, for the twenty-five years that have passed since Sacken's Catalogue have doubled the number of species and otherwise brought many changes; the careful labors of the author, aided by many gentlemen interested in the subject, have brought all this material together into a valuable and homogeneous volume.

12. *The Fauna and Geography of the Maldive and Laccadive Archipelagoes;* by J. STANLEY GARDINER, M.A. Vol. II, Part IV, pp. 807–921, with plates lxvii–lxxxvii and text illustrations 127–139. Cambridge, 1905 (The University Press).—This continuation of the account of the collections made by the expedition of 1899–1900, repeatedly noticed in this Journal, contains the following reports: 1. The Alcyonaria of the Maldives, Part III, by Sydney J. Hickson. 2. Marine Crustaceans, XIV, Paguridae, by Major Alcock. 3. Hydroids, by L. A. Borradaile. 4. Notes on Parasites, by A. E. Shipley. 6. Marine Crustaceans, XV, Les Alpheidae, by H. Coutière.

Supplement I, pp. 923–1040, with plates lxxxviii–c and text-illustrations 140–153. This supplement contains the following reports: 1. Marine Crustaceans, XVI, Amphipoda, by A. O. Walker. 2. Madreporaria, III Fungida, IV Turbinolidæ, by J. Stanley Gardiner. 3. Scyphomedusae, by Edward T. Browne. 4. Coleoptera, by D. Sharp. 5. The Cephalopoda, by W. E. Hoyle. 6. Notes in the Collection of Copepoda, by R. Norris Wolfenden.

13. *The American Museum Journal.* Published quarterly by the American Museum of Natural History, New York City.—The second number of volume v, "the Brontosaurus number," contains an account of the mounted skeleton put on exhibition in February, 1905. It also describes the two bird groups recently completed in the museum, one of Flamingos, the other of the summer bird-life of San Joaquin valley, California; the former is particularly striking and successful.

14. *Cold Spring Harbor Monographs.* Published by the Brooklyn Institute of Arts and Sciences, March, 1905.—The following additional numbers have been issued.

IV. The Life History of Case Bearers: 1, Chlamys plicata; by Ella Marion Briggs, 12 pp., with one plate and eleven text-figures.

V. The Mud Snail: Nassa obsoleta; by Abigail Camp Dimon, 48 pp., with two plates.

15. *Montana Agricultural College Science Studies; Botany.* Published quarterly by the College, Bozeman, Montana, 1905.—Numbers 1, 2 and 3 of volume i, 139 pp., issued together, contain the following papers:

I. A century of Botanical Exploration in Montana, 1805–1905, Collectors, Herbaria and Bibliography; by J. W. Blankinship.

II. Supplement to the Flora of Montana, additions and corrections; by J. W. Blankinship.

III. Common names of Montana Plants; by J. W. Blankinship and Hester F. Henshall. This is accompanied by an excellent colored plate of the pretty Bitter-root (*Lewisia rediviva.*)

III. Miscellaneous Scientific Intelligence.

1. *Vom Kilimandscharo zum Meru;* von C. Uhlig. Zeitschrift für Erdkunde, Berlin, Jahrg. 1904, No. 9 und 10.—This preliminary account of a journey of exploration in German East Africa contains much that is of interest. In reading the opening pages one cannot help reflecting how greatly the task of exploration in eastern Central Africa has been simplified in the last two or three years by the opening up of the Uganda Railway. The long and trying journey across the eastern desert region, which exhausted so much of strength, energy and resources before the real work began, is now performed in comparatively few hours. Thus our author leaves the coast on the 12th of September, and nine days later with his caravan is at Moschi on the lower slope of Kilimandjaro, ready to commence the ascent.

This he made from the eastern side without apparently any serious difficulty beyond the suffering entailed by the sudden change from the tropics to an arctic region. It will be recalled that Kilimandjaro has two summit peaks, a higher snow-capped one to the west called Kibo, and a lower one to the east called Kimawenzi or Mawenzi; these are separated by a deep saddle. Uhlig reached a height of about 19,500 feet on Kibo, but was unable to attain the highest point, which was about 200 feet more above him. He gives a number of interesting details concerning the snow and glacier formations accompanied by excellent photographs. Since the last ascent by Hans Meyer the amount of ice and snow appears to have distinctly increased. One striking feature was the occurrence along the snow slopes of long processions of weird and bizarre-shaped figures several feet high, similar to those observed, of much greater size, in the Andes, amd to which the name of "nieve penitente" has been given from the suggestion which they offer of processions of white-

robed penitents. Uhlig remarks that those he saw much more resembled trains of white poodles, rabbits and the snow men made by children than penitents. He ascribes their formation to the ablation from insolation and the dryness of the air, though other factors must be sought to explain their regularity of arrangement, as they appear in two distinct lines, one up and down the slope, the other at right angles, i. e. along contour lines. The mention of this arrangement by Uhlig suggests that perhaps cracking of the hardened snow into such systems, combined with the agencies mentioned above, may explain the phenomenon.

He also made a second ascent of Kibo from the south into the glacier zone and discovered a new one, not previously mapped, to which the name of Richter glacier is given. A fine photograph of Kibo from the south shows a great snow-covered dome with long glacial tongues reaching down from it.

After this work on Kilimandjaro, Uhlig turned his attention to Meru, a great volcano which rises to the westward. Its height is about 15,200 feet. His first ascent was made from upper Aruscha on the south flank, at an elevation of about 4,500 feet. At 7,000 feet a girdle composed of dense masses of bamboos was encountered, which lasted to about 8,800 feet, and which required the greatest efforts to penetrate. It appears quite similar to the bamboo zone which Gregory encountered on Mt. Kenia, and which he found so difficult to surmount. Above this the mountain offered no especial difficulties aside from the extraordinary steepness of its slopes. Towards its upper limit the flora assumes the distinctly alpine character noted on the other great volcanoes of equatorial Africa. Some forms of vegetation, grasses, compositæ and *Arabis albida*, persist even to the top. No snow was found on Meru, its summit falling over 2,000 feet short of the snow-line on the neighboring Kilimandjaro. Nor were any marks of a former period of glaciation visible, although on Kilimandjaro, according to Meyer, the glaciation once extended some 3,000 feet lower than at present, and Gregory found evidences of much more extended glaciation on Kenia than it now shows. It is possible, however, that Meru may have had small hanging glaciers.

At the summit Uhlig found himself on the edge of a vast crater, whose precipitous walls fell beneath him, over 4,000 feet to the bottom. The highest point, on the opposite wall, he attempted in a second ascent from the northeast, but was unable to attain.

Meru is a concentric crater which shows several periods of volcanic activity. There is an outward somma with broad opening to the east. Within this and close to it is an inner somma with a narrow opening to the west through it and the outer one. Within these is the deep caldera mentioned above with relatively level surface, on the south side of which and near the encircling wall, rises an ash cone which Uhlig believes to have very recently been in an active condition. The caldera is about one and a half miles broad.

Mügge, who studied the rock specimens brought back by Fischer* from his journeys in equatorial Africa, found the sam-

* Neues Jahrb. für Min., Beil. Bd. iv.

ples collected near the base of Meru to be of tephrite, leading to the suspicion that the volcano was built up of extrusive magmas of alkalic nature. This was fully confirmed by the material collected by Uhlig, the preliminary study showing it to consist of varieties of the phonolite-tephrite family. There is thus added another instance to confirm the highly alkalic character of the East African petrographic province, whose nature and extent through the studies of Hyland, Gregory, Prior, Lacroix and others, we are now beginning to appreciate. Now that the way has been opened into eastern equatorial Africa, we may expect that detailed studies of the region, such as Uhlig has been making in the Kilimandjaro region, will furnish in geography, in geology and in other fields of science, results of great importance and interest. L. V. P.

2. *Glacial Studies in the Canadian Rockies and Selkirks.*—A paper upon the above subject, by W. H. SCHERZER, is contained in Part 4, Vol. II, of the Quarterly Issue of the Smithsonian Miscellaneous Collections. This gives an account of the results obtained in connection with the Smithsonian Expedition of 1904. It is made particularly interesting by a series of excellent illustrations reproduced from photographs. Many of the details of glacial structure are particularly well shown; as, for example, the Forbes "dirt bands," the "dirt stripes," the stratification and shearing exhibited in the glacial front, also the various forms of moraines under many different conditions.

3. *The Solar Observatory of the Carnegie Institution of Washington;* by GEORGE E. HALE. 22 pp. with 5 plates. Contributions from the Solar Observatory, Mt. Wilson, California, No. 2.—This second contribution from the Mt. Wilson Solar Observatory (see p. 473 of the June number) details the special objects aimed at in its construction and the particular lines of work which it is proposed to carry through. An account is given also regarding the erection of the Snow telescope, sent out by the University of Chicago, and also the progress made in the construction of other buildings. The present staff of the Observatory is as follows: Director, George E. Hale; Astronomer and Superintendent of Instrument Construction, G. W. Ritchey; and Assistants, Ferdinand Ellermann and Walter S. Adams.

4. *United States Naval Observatory*, Rear-Admiral Colby M. Chester, U. S. N., Superintendent. Second series. Vol. IV, Appendix IV. The present status of the Use of Standard Time; by EDWARD E. HAYDEN, Lieut. Commander, U. S. N. 28 pp. Washington, 1905.—This paper explains the use of "standard time" and shows the remarkable extension of this system over the world.

5. *Publications of West Hendon House Observatory, Sunderland.* No. III, 1905. Pp. xi, 122, with 9 plates.—This volume contains the results of an extended series of observations by Mr. T. W. Backhouse, upon certain variable stars, made during the years 1866–1904.